**NOT MEASUREMENT SENSITIVE**

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# DEPARTMENT OF DEFENSE
# INTERFACE STANDARD

## DIGITAL MESSAGE TRANSFER DEVICE SUBSYSTEMS

AMSC N/A AREA TCSS

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# FOREWORD

This military standard is approved for use by all Departments and Agencies of the Department of Defense (DoD). It applies to all inter- and intra-Department of Defense (DoD) digital message transfer devices (DMTDs) and command, control, communications, computers and intelligence ($C^4I$) systems that exchange information with DMTDs.

This standard contains technical parameters for the data communications protocols that support DMTD interoperability. It provides mandatory system standards for planning, engineering, procuring, and using DMTDs in tactical digital communications systems. This standard specifies the lower layer (Physical through Intranet) protocol for interoperability of $C^4I$ systems over combat net radio (CNR) on the battlefield. This standard provides the information required to pass digital data via CNR on the battlefield.

The Preparing Activity (PA) for this standard is USACECOM, ATTN: AMSEL-SE-CD (Mr. E. Robinson), Fort Monmouth, NJ 07703. The custodians for the document are identified in the Defense Standardization Program, "Standardization Directory (SD-1)" under Standardization Area Data Communication Protocol Standards (DCPS).

Beneficial comments (recommendations, additions, deletions) and any pertinent data that may be of use in improving this military standard should be addressed to the PA at the above address by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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| APPENDIX | | |
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# 1. SCOPE

1.1 Purpose. This document promulgates the minimum essential technical parameters in the form of mandatory system standards and optional design objectives for interoperability and compatibility among DMTDs, and between DMTDs and applicable $C^4I$ systems. These technical parameters are based on the data communications protocol standards specified herein to ensure interoperability.

1.2 Scope. This document identifies the procedures, protocols, and parameters to be applied in specifications for DMTDs and $C^4I$ systems that exchange information with DMTDs. This document addresses the communications protocols and procedures for the exchange of information among DMTDs, among $C^4I$ systems, and between DMTDs and $C^4I$ systems participating in inter- and intra-Service tactical networks.

1.3 Application guidance. This document applies to the design and development of new equipment and systems, and to the retrofit of existing equipment and systems.

1.4 System standards and design. The parameters and other requirements specified in this document are mandatory system standards if the word shall is used in connection with the parameter value or requirement under consideration. Non-mandatory design objectives are indicated in parentheses after a standardized parameter value or by the word should in connection with the parameter value or requirement under consideration. Unless stated otherwise, the following convention is used in the figures of MIL-STD-188-220: Least Significant Bit (LSB) is always shown to the LEFT, and Most Significant Octet is always shown to the RIGHT.

# 2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, and 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the current issue of the DoD Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARDS

FEDERAL

| | |
|---|---|
| FED-STD-1037 | Glossary of Telecommunication Terms |

MILITARY

| | |
|---|---|
| MIL-STD-188-100 (Series) | Common Long Haul and Tactical Communications System Technical Standards |
| MIL-STD-188-110 | Equipment Technical Design Standards for Common Long Haul/Tactical Data Modems |
| MIL-STD-188-114 | Electrical Characteristics of Digital Interface Circuits |
| MIL-STD-188-200 | System Design and Engineering Standards for Tactical Communications |
| MIL-STD-2045-14502-1 | Information Technology DoD Standardized Profile -- Internet Transport Profile for DoD Communications – Part 1: Transport and Internet Services |
| MIL-STD-2045-47001 | Interoperability Standard for Connectionless Data Transfer -- Application Layer Standard |

[Unless otherwise indicated, copies of federal and military standards are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.]

2.2.2 Other Government documents, drawings, and publications. None.

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents that are DoD- adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

2.3.1 International Organization for Standardization (ISO).

| | |
|---|---|
| ISO 3309 | Information Processing Systems -- Data Communication -- High-level Data Link Control Procedures -- Frame Structure |
| ISO 7498-1 | Information Processing Systems -- Open Systems Interconnection -- Basic Reference Model |
| ISO 8802-2 | Information Processing Systems -- Local Area Networks -- Part 2: Logical Link Control |

[ISO standards are available from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.]

2.3.2 International Telecommunications Union (ITU).

Formerly known as International Telephone and Telegraph Consultative Committee (CCITT)

| | |
|---|---|
| CCITT V.10 | Electrical Characteristics for Unbalanced Double-Current Interchange Circuits for General Use with Integrated Circuit Equipment in the Field of Data Communications. |
| CCITT V.33 | 14,400 Bits Per Second Modem Standardized for Use on Point-to-Point 4-wire Leased Telephone-Type Circuits. |
| CCITT V.36 | Modems for Synchronous Data Transmission Using 60-108 kHz Group Band Circuits. |
| CCITT X.21 | Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Synchronous Operation on Public Data Networks. |

[CCITT standards are available from Omnicom, 115 Park Street, South East, Vienna, VA 22180]

2.3.3 Internet Architecture Board (IAB)Standards.

| | |
|---|---|
| RFC 826 | An Ethernet Address Resolution Protocol -- or -- Converting Network Protocol Addresses to 48-bit Ethernet Addresses for Transmission on Ethernet Hardware |
| RFC 903 | A Reverse Address Resolution Protocol |
| RFC 1770 | IPv4 Option for Sender Directed Multi-Destination Delivery |

[RFCs are available from Network Information Center, 14200 Park Meadow Drive, Suite 200, Chantilly, VA 22021. The Network Information Center (NIC) can be reached, by phone, Monday through Friday, 7 AM through 7 PM, Eastern Standard time: 1-800-365-3642 and 1-703-802-4535. RFCs may also be obtained from the DS.INTERNIC.NET via FTP, WAIS, and electronic mail. Through FTP, RFCs are stored as rfc/rfcnnnn.txt or rfc/rfcnnnn.ps where 'nnnn' is the RFC number, 'txt' is a text file and 'ps' is a postscript file. Login as "anonymous" and provide your e-mail address as the password. Through WAIS, you may use either your local WAIS client or TELNET to DS.INTERNIC.NET and login as "wais" (no password required). Through electronic mail send a message to mailserv@ds.internic.net and include the following commands in the message body document -by-name RFC#### where #### is the RFC number without leading zeros or file /ftp/rfc/rfc####.yyy where 'yyy' is 'ps' or 'txt'. To obtain the complete RFC index, the subject line of your message should read "RFC index."]

2.3.4 Other. In parallel to the English specification found in this standard, several components of MIL-STD-188-220 also have been formally specified using Estelle. Estelle is a formal description technique based on communicating, extended finite state machines. Estelle is described in ISO 9074. The Estelle formal specifications are available via the CNR Implementation Working Group World Wide Web page: http://www-cnrwg.itsi.disa.mil.

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

# 3. DEFINITIONS

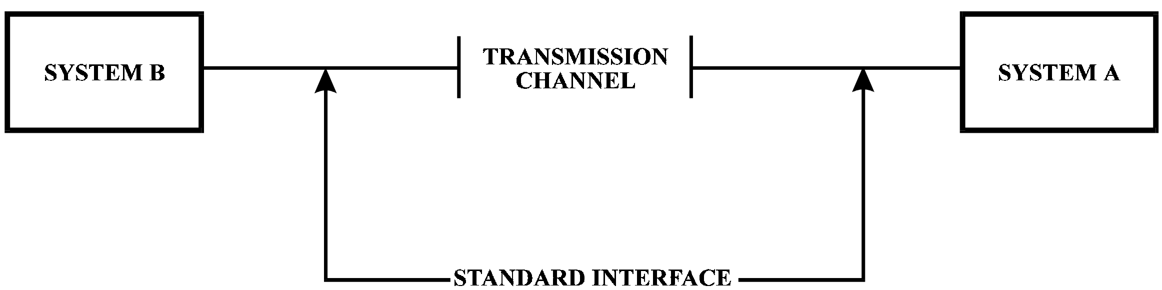
3.1 Definitions of terms. Definitions of terms used in this document are specified in FED-STD-1037.

3.2 Abbreviations and acronyms. Abbreviations and acronyms used in this MIL-STD are defined in Appendix A. Those listed in the current edition of FED-STD-1037 have been included for the convenience of the reader.

# 4. GENERAL REQUIREMENTS

4.1 Digital message transfer device. A DMTD is a portable data terminal device with limited message generation and processing capability. DMTDs are used for remote access to automated $C^4I$ systems and to other DMTDs. The environment encompasses point-to-point, point-to-multipoint, relay and broadcast transfer of information over data communications links.

4.2 Interoperability. Interoperability of DMTDs and associated $C^4I$ systems shall be achieved by implementing the standard interface for DMTD subsystems (see Figure 1) specified in this document. This standard defines the layered protocols for the transmission of single or multiple segment messages over broadcast radio subnetworks and point-to-point links. It provides the minimum essential data communications parameters and protocol stack required to communicate with other data terminal devices. These communications parameters and protocols will facilitate functional interoperability among DMTDs, and between DMTDs and applicable $C^4I$ systems within the layered framework described below. Electrical and mechanical design parameters are design-dependent and are outside the scope of this document. Interoperability considerations for terminal designers and systems engineers are addressed in 6.3 and Appendix B.




NOTES:

1. System A and System B (where either system, or both, can be a DMTD or a $C^4I$ system) may include modems, line drivers, error control algorithms, encryption devices, control units, and other devices as required to comply with this standard.

2. The transmission channel may include single and multichannel transmission equipment.

FIGURE 1. Standard interface for DMTD subsystems.

4.3 Framework. The communications and procedural protocols used in DMTD equipment shall support the layers of the functional reference model depicted in Figure 2. The DMTD functional reference model in Figure 2 is based on the ISO 7498 OSI seven-layer model and is for reference only. Figure 2 contains the framework that is used in this document for defining the protocols required to exchange information among DMTD subsystems, and between DMTD subsystems and applicable $C^4I$ systems. Figure 3 illustrates a representative time epoch of the basic frame structure supported by the DMTD subsystem. This standard describes the protocols at the following OSI layers:

a. Physical Layer

b. Data Link Layer
1. Network Access Control
2. Link Level Control

c. Network Layer (Intranet Layer)

Application Layer *

Presentation Layer *

Session Layer *

---

Transport Layer *

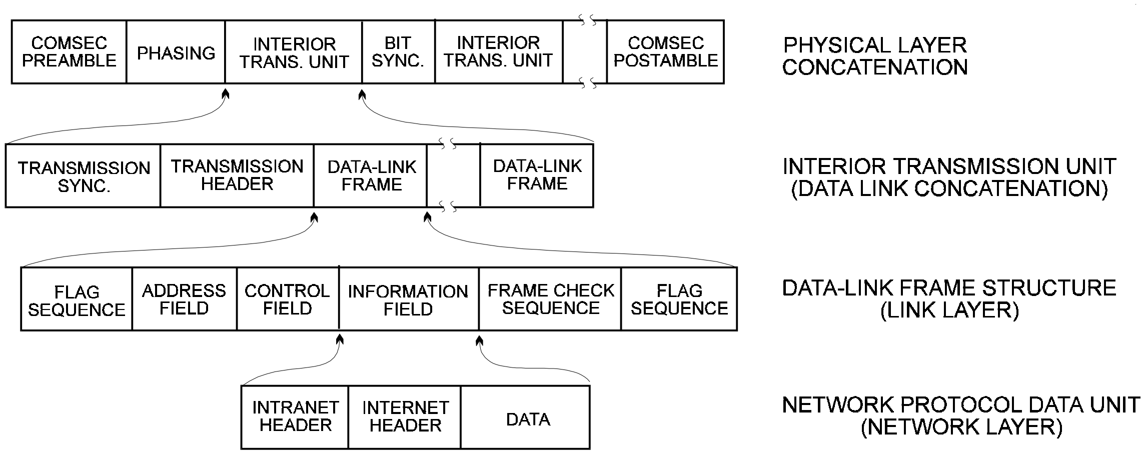
Network Layer

Data Link Layer

Physical Layer

* NOTE: These layers are not addressed in this standard.

FIGURE 2. DMTD functional reference model.




NOTES: Phasing if required, is applied before the first Interior Transmission Unit.

Bit Synchronization is applied between physically concatenated Interior Transmission Units.

The Network Protocol Data Unit may include an Internet header in addition to the required Intranet header.
This standard does not specify requirements for the Internet header.

FIGURE 3. Basic structure of DMTD protocol data units at the standard interface.

4.4 DMTD capabilities. The waveform and the protocols necessary to ensure end-to-end interoperability at the interface shall support the following capabilities:

a. Transmission in a half-duplex mode over radio, wireline, and satellite links;

b. Link encryption;

c. Point-to-point, multipoint, relay or broadcast connectivity between stations;

d. Asynchronous balanced mode of operation between two or more stations;

e. Network access control for network access management and collision avoidance;

f. Transport of bit-oriented or free-text (character-oriented) messages for information exchange in a variable message format over the link;

g. User data exchange using single or multiple frame packets;

h. Addressing conventions that support single, multiple, and global station broadcast addressing, as well as routing and relay;

i. Error control, for maintaining data integrity over the link, including frame check sequence (FCS), forward error correction (FEC), and time-dispersal coding (TDC);

j. Data-link frame acknowledgment, intranet frame acknowledgment and end-to-end, segment acknowledgment at the transport layer;

k. Intranet relay at the network layer; and

l. Topology update capability for the intranet.

# 5. DETAILED REQUIREMENTS

5.1 Physical layer. The physical layer shall provide the control functions required to activate, maintain, and deactivate the connections between communications systems. This standard does not address the electrical or mechanical functions normally associated with physical layer protocols.

5.1.1 Transmission channel interfaces. The transmission channel interfaces specified below define the transmission envelope characteristics (signal waveform, transmission rates, and operating mode) authorized at the standard interface between a DMTD and the transmission channel. The transmission channel may consist of wireline, satellite, or radio links.

5.1.1.1 Non-return-to-zero (NRZ) interface. This interface shall be used primarily with digital transmission equipment. A non-return-to zero (NRZ) signal waveform shall be used for this interface.

5.1.1.1.1 Waveform. The NRZ unbalanced and balanced waveforms shall conform to paragraphs 5.1.1.7 and 5.2.1.7, respectively, of MIL-STD-188-114A.

5.1.1.1.2 Transmission rates. The output transmission rates of the NRZ interface shall be the following bit rates: 75, 150, 300, 600, 1200, 2400, 4800, 9600, and 16000 bits per second (bps).

5.1.1.1.3 Operating mode. The NRZ interface shall support half-duplex transmission.

5.1.1.2 Frequency-shift keying (FSK) interface for voice frequency channels. This interface may be used. It is primarily associated with analog single-channel [3-kilohertz (Khz)] radio equipment. The frequency-shift keying (FSK) data modem characteristics shall conform to paragraph 5.2.2 of MIL-STD-188-110.

5.1.1.2.1 Waveform. The FSK modulation waveform shall conform to paragraph 5.2.2.1 of MIL-STD-188-110. The characteristic frequencies, in hertz (Hz), for transmission rates of 600 bps or less, and 1200 bps, shall be as shown in Table I.

5.1.1.2.2 Transmission rates. Output transmission rates of the FSK interface shall be the following bit rates: 75, 150, 300, 600, and 1200 bps.

5.1.1.2.3 Operating mode. The FSK interface shall support half-duplex transmission.

TABLE I. Characteristic frequencies of frequency-shift keying interface for voice frequency channels.

| PARAMETER | CHARACTERISTIC FREQUENCY (Hz) | |
|---|---|---|
| | 600 bps or less | 1200 bps |
| Mark Frequency | 1300 | 1300 |
| Space Frequency | 1700 | 2100 |

5.1.1.3 Frequency-shift keying (FSK) interface for single-channel radio. This interface, used within DoD, may also be used for North Atlantic Treaty Organization (NATO) single-channel radio applications. The FSK interface data modem characteristics shall conform to paragraph 5.1 of MIL-STD-188-110.

5.1.1.3.1 Waveform. The FSK modulation waveform shall conform to paragraphs 5.1.1 and 5.1.2 of MIL-STD-188-110. The characteristic frequencies are specified in Table II.

TABLE II. Characteristic frequencies of frequency-shift keying interface for single-channel radio.

| PARAMETER | CHARACTERISTIC FREQUENCY (Hz) |
|---|---|
| Mark Frequency | 1575 |
| Space Frequency | 2425 |

5.1.1.3.2 Transmission rates. Output transmission rates of the single-channel FSK interface shall be the following bit rates: 75, 150, 300, 600, and 1200 bps.

5.1.1.3.3 Operating mode. The single-channel FSK interface shall support half-duplex transmission.

5.1.1.4 Conditioned diphase (CDP) interface. This interface may be used. It is primarily associated with wideband wireline equipment.

5.1.1.4.1 Waveform. The CDP modulation waveform shall conform to paragraph 5.4.1.4 of MIL-STD-188-200. The unbalanced and balanced signal waveform shall conform to paragraphs 5.1.1.7 and 5.2.1.7, respectively, of MIL-STD-188-114.

5.1.1.4.2 Transmission rates. The output transmission rate of the CDP interface shall be 16 and 32 kilobits per second (kbps).

5.1.1.4.3 Operating mode. The CDP interface shall support half-duplex transmission.

5.1.1.5 Differential phase-shift keying (DPSK) interface for voice frequency channels. This interface may be used. It is primarily associated with analog (nominal 4-Khz voice frequency) wireline and radio equipment. Differential phase-shift keying (DPSK) modulation data modem (2400 bps) and phase-shift keying (PSK) modulation data modem (1200 bps) characteristics shall conform to the applicable requirements of MIL-STD-188-110.

5.1.1.5.1 Waveform. The DPSK modulation waveform shall conform to Appendix A of MIL-STD-188-110. The PSK modulation waveform shall conform to paragraph 5.3 of MIL-STD-188-110.

5.1.1.5.2 Transmission rates. The output transmission rate of the DPSK and PSK interfaces shall be 2400 and 1200 bps, respectively.

5.1.1.5.3 Operating mode. The DPSK and PSK interfaces shall support half-duplex transmission.

5.1.1.6 Packet mode interface. This interface shall use a modified CCITT X.21 half-duplex synchronous interface for transferring digital data across the interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE). The packet interface shall be a modified CCITT X.21 interface with a CCITT V.10 electrical circuit between a DTE (DMTD or $C^4I$ system) and the DCE.

5.1.1.6.1 Waveform. The electrical characteristics of the packet mode interface shall be identical to CCITT V.10 for interfaces to voice band modems.

5.1.1.6.2 Transmission rates. The DTE device shall be required to accept signal timing from the DCE (radio) at 16 Kbps. The DTE shall be required to synchronize to the DCE signal timing and accept data at the supplied signaling timing rate. In the packet mode, the radio provides signal timing to support 16 Kbps data transfers between the radio and the DTE.

5.1.1.6.3 Operating mode. The packet mode interface shall support half-duplex transmission.

5.1.1.7 Amplitude shifting keying (ASK) interface. This interface is used primarily with analog voice grade radios to transmit digital data.

5.1.1.7.1 Waveform. The ASK waveform is a band limited NRZ waveform with average white Gaussian noise added to it. The ASK signal shall be a bipolar signal nominally centered around ground. However due to the radio automatic gain control performance, the ASK signal may have a direct current (DC) component. The ASK signal-to-noise ratio shall be in the range of 0 to 12 decibels (dB). The ASK signal shall be demodulated using an optimal bit synchronizer with a bit error rate performance of 1.5 dB from theoretical.

5.1.1.7.2 Transmission rates. The output transmission rates of the ASK interface shall be the following bit rates: 2400, 4800, 9600 and 16000 bits per second.

5.1.1.7.3 Operating mode. The ASK interfaces shall support half-duplex transmission.

5.2 Physical-layer protocol.

5.2.1 Physical-layer protocol data unit. The transmission frame shall be the basic protocol data unit (PDU) of the physical layer and shall be as shown in Figure 4. Figure 4a presents the transmission frame structure for traditional COMSEC (backward-compatible mode). Traditional COMSEC is used in this document to denote systems with the COMSEC equipment placed external to the $C^4I$ system. Figure 4b presents the transmission frame structure with COMSEC embedded in the $C^4I$ system (embedded mode). Figure 4c presents the transmission frame structure without COMSEC.

| | | | | |
|---|---|---|---|---|
| COMSEC PREAMBLE | PHASING | TRANSMISSION SYNCHRONIZATION | DATA FIELD | COMSEC POSTAMBLE |

Figure 4a. Transmission frame structure with external COMSEC.

| | | | |
|---|---|---|---|
| PHASING | TRANSMISSION SYNCHRONIZATION WITH COMSEC MESSAGE INDICATOR | DATA FIELD | COMSEC POSTAMBLE |

Figure 4b. Transmission frame structure with embeddedl COMSEC.

| | | |
|---|---|---|
| PHASING | TRANSMISSION SYNCHRONIZATION | DATA FIELD |

Figure 4c. Transmission frame structure with no COMSEC.

FIGURE 4. Transmission frame structure.

5.2.1.1 Communications security preamble and postamble. These fields are present when link encryption is used. The COMSEC preamble field shall be used to achieve cryptographic synchronization over the link. The COMSEC postamble field shall be used to provide an end-of-transmission flag to the COMSEC equipment at the receiving station. These fields and the COMSEC synchronization process are described in Appendix D (D5.1.1 and D5.1.4, respectively).

5.2.1.2 Phasing. Phasing shall be a string of alternating ones and zeros, beginning with a one, sent by the DTE. For Packet Mode interfaces, the length of this field shall be 0. Phasing is described in C3.2b.

5.2.1.3 <u>Transmission synchronization field</u>. The structure of the transmission synchronization field is dependent on the mode of operation. The three modes are Asynchronous for use with DCEs that present modulated data without a clock, Synchronous for use with DCEs that present a clock and data interface and Packet for use with DCEs that require no frame synchronization. The structures for Asynchronous and Synchronous modes are shown in Figure 5. The structure for the Packet Mode is described in 5.2.1.3.3.

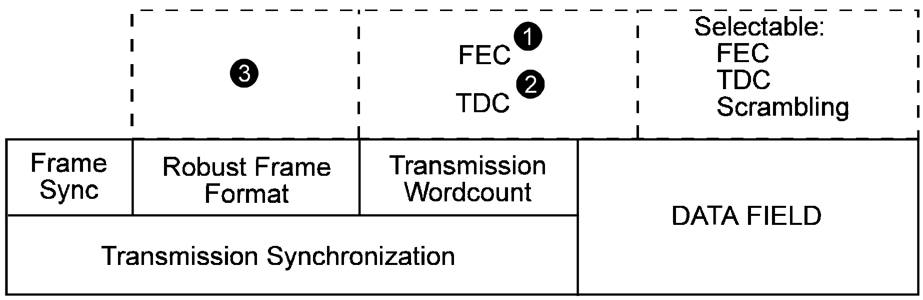



Figure 5a. With external COMSEC or No COMSEC.

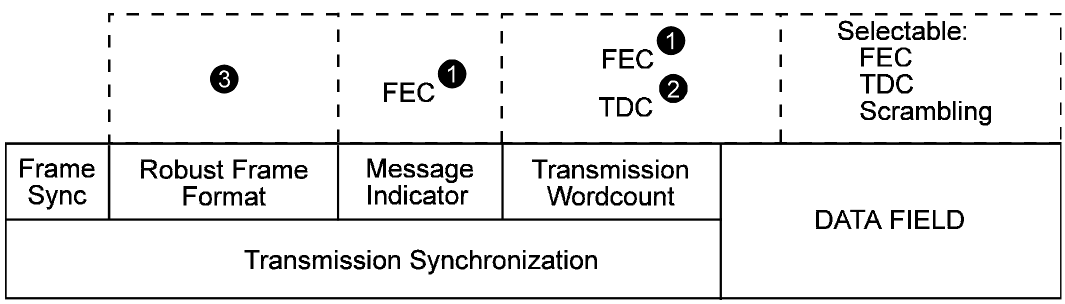



Figure 5b. With Embedded COMSEC.

Notes:

❶ Golay FEC is applied to the Transmission Wordcount, message Indicator and Transmission Header fields in Asynchronous and Synchronous Modes. (The Transmission Header is the leading portion of the Data Field as described in 5.3.1.)

❷ TDC is applied to the Transmission Wordcount and Transmission Header fields in Asynchronous and Synchronous Modes. (The Transmission header is the leading portion of the Data Field as described in 5.3.1.)

❸ The Robust Frame Format subfield is optional and is used only when implementing the Robust Communications Protocol described in Appendix J.

FIGURE 5. <u>Transmission synchronization field</u>.
(Synchronous and Asynchronous Mode)

5.2.1.3.1 Asynchronous mode transmission synchronization field. The Asynchronous Transmission Synchronization field shall be composed of the following:

a. Frame Synchronization

b. Robust Frame Format (Optional)

c. Message Indicator (embedded COMSEC only)

d. Transmission Word Count

5.2.1.3.1.1 Frame synchronization subfield. This subfield shall consist of the fixed 64-bit synchronization pattern shown in Figure 6 or Figure 7. The receiver shall correlate for the frame synchronization pattern. A pattern shall be detected if 13 or fewer bits are in error with non-inverted or inverted data. If the correlation detects an inverted synchronization pattern, all received data shall be inverted before any other received processing is performed. If the frame synchronization subfield shown in Figure 6 is detected before the robust frame synchronization subfield shown in Figure 7, the receiver shall assume the optional robust processing is not requested for this transmission.

| LSB | MSB |
|---|---|
| 0110010011110010111100101001011010010000010111101010110111011001 | |

FIGURE 6. Frame synchronization subfield.

If the robust frame synchronization pattern shown in Figure 7 is detected, the robust frame format subfield shall be decoded to determine what physical level processing is required for data reception. If the robust frame synchronization pattern shown in Figure 7 is used, the frame synchronization pattern shown in Figure 6 shall not be used.

| LSB | MSB |
|---|---|
| 0100100111001100111011011011111100000010011011010101111000111000 | |

FIGURE 7. Robust frame synchronization subfield.

5.2.1.3.1.2 Robust frame format subfield. The robust frame subfield is an optional field that is used only with the robust frame synchronization subfield shown in Figure 7. The robust frame format subfield is a seven bit field which specifies the format of the transmitted frame. The robust frame format subfield shall be formatted with multi-dwell majority vote 3 out of 5 Bose-Chaudhuri-Hocquenghem (BCH) (15,7) coding and no scrambling or convolutional encoding. The bits are defined in Tables III, IV and V.

TABLE III. Robust frame format.

| Bit(s) | Fields |
|---|---|
| 0 (LSB) | Multi-Dwell Flag |
| 1 | Scrambling Flag |
| 2, 3, 4 | Multi-Dwell Transmission Format |
| 5,6 | Convolutional Coding Constraint Length |

TABLE IV. Multi-dwell transmission format.
(The Least Significant Bit is shown on the Left)

| | |
|---|---|
| 000 | Single BCH(15,7) word<br>32 BIT SOP, 11 64-bit segments per packet |
| 100 | Majority Vote 2 out of 3 BCH(15,7) word<br>64 BIT SOP, 13 64-bit segments per packet |
| 010 | Majority Vote 3 out of 5 BCH(15,7) word<br>64 BIT SOP, 13 64-bit segments per packet |
| 110 | Majority Vote 3 out of 5 BCH(15,7) word<br>64 BIT SOP, 6 64-bit segments per packet |

TABLE V. Convolutional coding constraint length codes.
(The Least Significant Bit is shown on the Left)

| | |
|---|---|
| 00 | Constraint Length 3 |
| 10 | Constraint Length 5 |
| 01 | Constraint Length 7 |
| 11 | Convolutional Coding Disabled |

5.2.1.3.1.3 Message indicator. The message indicator field is contained within the transmission synchronization field only when COMSEC is embedded in the host. The message indicator field is defined in Appendix D (D5.1.1.3 and D5.2.3). Golay forward error correction (FEC) is applied to the TWC, Message Indicator (with embedded COMSEC) and Transmission Header in Asynchronous and Synchronous Modes.

5.2.1.3.1.4 Transmission wordcount (TWC) subfield. The TWC is a 12-bit value calculated by the transmitting station to inform the receiving station of the number of 16-bit words (after any appropriate FEC encoding, TDC fill or zero bit insertion) that form the data field(s) of the transmission frame. The maximum TWC is 4095 ($2^{12}$-1). The value provided by the 12 information bits is binary-encoded. The maximum number of words is dependent on the maximum number of bits allowed in the data field of a transmission frame. It is possible that the number of bits in the data field will not be evenly divisible by 16. In that case, the word count shall be rounded to the next higher integer. TDC is applied to the TWC and Transmission Header in Asynchronous and Synchronous Modes. Golay FEC is applied to the TWC, Message Indicator (with embedded COMSEC) and Transmission Header in Asynchronous and Synchronous Modes.

5.2.1.3.2 Synchronous mode transmission synchronization field. The Synchronous Transmission Synchronization field shall be composed of the following:

a. Frame Synchronization

b. Robust Frame Format (optional)

c. Message Indicator (embedded COMSEC only)

d. Transmission Word Count

5.2.1.3.2.1 Frame synchronization subfield. The Synchronous Mode Frame Synchronization subfield is the same as the Asynchronous Mode Frame Synchronization subfield defined in 5.2.1.3.1.1 and shown in Figures 6 and 7.

5.2.1.3.2.2 Robust frame format subfield. The Synchronous Mode Robust Frame Format subfield is the same as the Asynchronous Mode Robust Frame Format subfield defined in 5.2.1.3.1.2.

5.2.1.3.2.3 Message indicator. The format of the Synchronous Mode Message Indicator field is the same as for the Asynchronous Mode Message Indicator field defined in 5.2.1.3.1.3.

5.2.1.3.2.4 Transmission wordcount. The Synchronous Mode TWC format is the same as the Asynchronous Mode TWC defined in 5.2.1.3.1.4.

5.2.1.3.3 Packet mode transmission synchronization field. This field consists of at least 4 HDLC flags corresponding to the following bit pattern shown in Figure 8.

| LSB | MSB |
|---|---|
| 01111110011111100111111001111110 | |

FIGURE 8. Packet mode transmission synchronization field.

5.2.1.3.4 Multi-dwell protocol. The multi-dwell protocol provides the capability to transmit data over frequency hopping radios without internal buffering. The multi-dwell protocol is described in Appendix J.

a. The multi-dwell start of packet (SOP) header size and segment count redundancy are configured depending upon the channel environment and are not changed on a per transmission basis.

b. The upper layer indicates the size of the transmission in the PL-Unitdata Request data length. The physical layer shall use the data length information to determine the most efficient multi-dwell parameters to use for data transmission. The optional multi-dwell segment count may be used by the upper layer to override the automatic determination of the multi-dwell transmission parameters made by the physical layer. For a multi-dwell reception, the upper layer will use the timing of the transition of the PL-Status Indication Network Activity from "busy with data" to "clear" to indicate the time of reception of the last bit of data.

5.2.1.4 Data field. The data field shall contain the string of bits created by the data-link layer following the procedures for framing, zero bit insertion, concatenation, FEC, TDC, and scrambling. FEC, TDC and Scrambling are not applied when Packet Mode is used.

5.2.1.5 Bit synchronization field. This field shall be used to provide the receiver a signal for re-establishing bit synchronization. Bit synchronization is used only between physically concatenated frames in Asynchronous Mode. The bit synchronization field shall be a 64-bit pattern that consists of alternating ones and zeros, beginning with a one.

5.2.2 Net access control related indications.

a. The net busy information is conveyed to the upper layer protocol (data link) through a status indication. Upon detection of a net busy, the net busy indicator shall be set. The net busy sensing indicator shall be reset when neither digital data nor voice is detected by the net busy sensing function. Appendix C (C4.1) describes the net busy sensing function.

b. The net access control algorithm described in Appendix C needs the transmitter to know when the last bit of data is transmitted, and the receiver to know when the last bit of data is received.

5.2.3 Physical-layer to upper-layer interactions. At least three primitives are used to pass information for the sending and receiving of data across the upper layer boundary.

a. Requests for transmission of data are sent by the upper layer, using the physical layer (PL) Unitdata Request primitive with the following parameter:

PL-Unitdata Request
- Data/Data length
- FEC/TDC/Scrambling
  - No FEC, No TDC, No Scrambling
  - No FEC, No TDC, Scrambling
  - FEC, No TDC, No Scrambling
  - FEC, No TDC, Scrambling
  - FEC, TDC, No Scrambling
  - FEC, TDC, Scrambling
- Multi-dwell transmission format segment count
  - 6 segments per packet
  - 11 segments per packet
  - 13 segments per packet

b. Indication of data received is provided to the upper layer through the Unitdata Indication primitive with the following parameter:

PL-Unitdata Indication
- Data/Data length
- FEC/TDC/Scrambling
  - No FEC, No TDC, No Scrambling
  - No FEC, No TDC, Scrambling
  - FEC, No TDC, No Scrambling
  - FEC, No TDC, Scrambling
  - FEC, TDC, No Scrambling
  - FEC, TDC, Scrambling
- Multi-dwell transmission format segment count
  - 6 segments per packet
  - 11 segments per packet
  - 13 segments per packet

c. Net activity status information is provided to the upper layer through a Status Indication with the following parameters:

PL-Status Indication
- Net activity
  - net clear
  - net busy

busy with/data
busy with/voice
Transmission Status
transmit complete/idle
in-process
transmit aborted

5.3 Data-link layer. The data-link layer shall provide the control functions to ensure the transfer of information over established physical paths, to provide framing requirements for data, and to provide for error control. Zero bit insertion is applied to the Transmission Header and Data Link Frame.

5.3.1 Transmission header. The Transmission Header is sent before each data field transmission. The Transmission Header consists of a two-octet Transmission Information field, a 32-bit FCS, in accordance with paragraph 5.3.4.2.5, and is bounded by Flags in accordance with paragraph 5.3.4.2.1. The Transmission Information field contains Selection bits and a Transmission Queue subfield which indicates the transmitting station queue length. The Transmission Header format is shown in Figure 9. Golay FEC and TDC are applied to the entire Transmission Header (except when the Packet Mode Interface described in paragraph 5.1.1.6 is used at the Physical Layer), including leading and trailing flags, Message Indicator (with embedded COMSEC) and TWC. The TWC, Message Indicator and transmission header shall have Golay FEC applied when operating in the Asynchronous and Synchronous modes. TDC (7x24) bit interleaving shall be applied in unison with the FEC on the TWC and transmission header. The data shall be formatted into a TDC block composed of seven (7) 24-bit Golay (24,12) codewords in a manner analogous to 5.3.14.3. There are 168 FEC-encoded bits with this TDC.

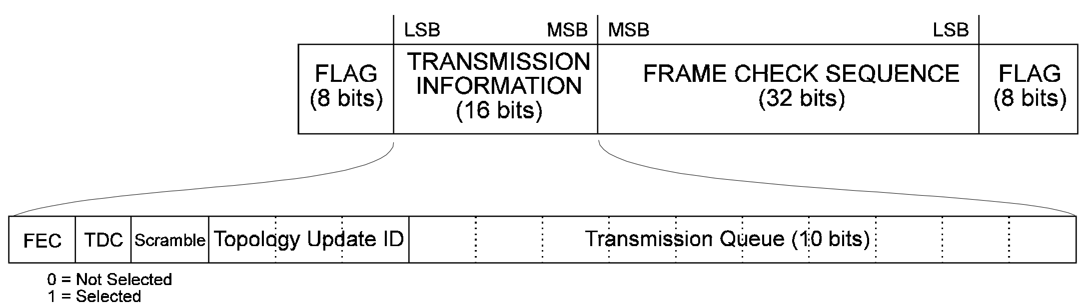



FIGURE 9. Transmission header.

5.3.1.1 Selection bits. The first three bits of the Transmission Information field selects FEC, TDC and Scrambling, respectively, on or off for the remainder of the physical layer data field. A zero indicates "off" and a one indicates "on" in these bit positions. Regardless of the setting of these three bits, Golay FEC/TDC is applied and Scrambling is not applied to the entire Transmission Header. Scrambling, if used, shall be applied before any FEC and TDC is applied.

FEC, TDC and scrambling are not applied when the Packet Mode Interface described in paragraph 5.1.1.6 is used at the Physical Layer.

5.3.1.2 Topology update identifier. This subfield shall contain the least significant three bits of the Topology Update ID used in the most recent Topology Update message (see 5.4.1.2). If no Topology Update messages have been sent, this subfield shall be all zeros.

5.3.1.3 Transmission queue subfield. This subfield is used to support the radio embedded net access delay (RE-NAD) process and the deterministic adaptable priority net access delay (DAP-NAD) process. The entire field is 10-bits long with the first two bits ('T'-bits) indicating how the rest of the subfield is interpreted. The format of the transmission queue subfield is shown in Figure 10.

5.3.1.3.1 T-bits. The two left-most bits in the transmission queue subfield are the T-bits. The bit sequence interpretations are indicated in Figure 10. The transmission queue subfield has a variable format depending on which of the following uses are intended:

a. T-bits = 00 The transmission queue subfield does not contain information and is ignored.

b. T-bits = 01 The transmission queue subfield is used in conjunction with RE-NAD. This subfield contains queue precedence (in bit positions 2-3) and queue length (bit positions 4-7). Bit positions 8 and 9 are spare and ignored.

c. T-bits = 10 The transmission queue subfield is used in conjunction with DAP-NAD. This subfield contains Data Link Precedence (in bit positions 2 and 3) and First Subscriber Number (in bit positions 4-9).

d. T-bits =11 This bit sequence is INVALID and shall be ignored. Data link frame(s) after this header shall be processed normally.

T-Bits

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | Transmission Queue Subfield Ignored | | | | | | | |
| 0 | 1 | Queue Prec. | | Queue Length | | | | spare | |
| 1 | 0 | Data Link Prec. | | First Subscriber Number | | | | | |
| 1 | 1 | Invalid/Ignored | | | | | | | |

FIGURE 10. Transmission queue subfield formats.

5.3.1.3.2 Queue precedence. The queue precedence component indicates the highest precedence level of information type frames in the queue.

The precedence levels and bit sequences are:

| Precedence | Bit 2 | Bit 3 | Value |
|---|---|---|---|
| Urgent | 0 | 0 | 0 |
| Priority | 1 | 0 | 1 |
| Routine | 0 | 1 | 2 |
| Reserved | 1 | 1 | 3 |

5.3.1.3.3 Queue length. The queue length component indicates the number of concatenated frame sequences required to transmit all of the highest precedence messages in the transmission queue at the time the transmission was created. This number may be used by receiving station to calculate the average network member's queue length. This average is used in calculation of the continuous scheduler for the Radio Embedded channel access procedure (C4.4.4).

5.3.1.3.4 Data link precedence. This subfield consists of two bits and contains a value that indicates the highest precedence of any message that is contained in the physical frame. It shall contain the value 0 if an urgent message is in the frame, 1 if a priority but no urgent message is in the frame and 2 if neither an urgent nor priority message is in the frame. The variable NP in the equations defined in C4.4.5.2 is set equal to the contents of the highest precedence Data Link precedence field in any (possibly concatenated) physical frame contained in the most recent reception.

The precedence levels and bit sequences for the Data Link precedence field are:

| Precedence | Bit 2 | Bit 3 | Value |
|---|---|---|---|
| Urgent | 0 | 0 | 0 |
| Priority | 1 | 0 | 1 |
| Routine | 0 | 1 | 2 |
| Undefined | 1 | 1 | 3 |

Undefined precedence values shall be handled as routine.

5.3.1.3.5 First subscriber number. This subfield consists of 6 bits and designates the number of the subscriber that is to have the first net access opportunity at the next net access period (the one immediately following this transmission). The number of the subscriber that has the first net access opportunity is the variable FSN in the equations defined in Appendix C (C4.4.5.2).

Bit coding for First Subscriber Number is:

| 1st Subscriber # | Bit: 4--->9 |
|---|---|
| Illegal | 000000 |
| 1 | 100000 |
| 2 | 010000 |
| . | .. |
| . | .. |
| . | .. |
| 63 | 111111 |

5.3.2 Net access control. The presence of multiple subscribers on a single communications net requires a method of controlling the transmission opportunities for each subscriber. To minimize conflicts, the net busy sensing function and net access control (NAC) procedures regulate transmission opportunities for all participants on the net. Random - Net Access Delay (R-NAD), Hybrid - Net Access Delay (H-NAD), Prioritized - Net Access Delay (P-NAD), Radio Embedded Net Access Delay (RE-NAD) and Deterministic Adaptable Priority - Net Access Delay (DAP-NAD) are the authorized NAC procedures at this interface. Appendix C defines the NAC parameters for R-NAD, H-NAD, P-NAD, DAP-NAD, and RE-NAD.

5.3.2.1 Scheduler. When the net access is embedded in the radio, a scheduler may be implemented in the DTE or communications processor to organize radio access throughout the network. The scheduler is used to provide a random distribution of timing for channel requests. When a station has data to transmit, it shall calculate the scheduler timer as indicated in Appendix C (C4.4.4.1). When this timer expires, the link layer shall first determine that the previous frame concatenation was transmitted by the physical layer. If the frame concatenation was not transmitted, the link layer shall request its transmission. If a higher precedence individual frame becomes available for transmission, the concatenated frames shall be re-built to include the higher precedence frame. If the previous frame concatenation was transmitted, the link layer shall build a new frame concatenation. This frame concatenation shall then be passed to the physical layer for transmission. Both randomized and immediate scheduler modes are specified in Appendix C (C4.4.4.1.1 and C4.4.4.1.5, respectively).

5.3.3 Types of procedures. Four types of operation for data communication between systems are defined to provide basic connectionless and connection mode operations:

Type 1 - Unacknowledged Connectionless Operation
Type 2 - Connection-mode Operation
Type 3 - Acknowledged Connectionless Operation
Type 4 - Decoupled Acknowledged Connectionless Operation

Types and services 1 through 3 are based on ISO 8802-2. The Type 1 and Type 3 connectionless operations are mandatory for implementation in all systems. The Type 2 connection mode is optional for this interface. The Type 4 connectionless mode (decoupled ACK) is optional.

Estelle language formal specifications of these four types of data link operation are available via the CNR Implementation Working Group World Wide Web page: http://www-cnrwg.itsi.disa.mil.

5.3.3.1 Type 1 operation. For the purpose of this protocol, Type 1 operation will designate both of the ISO 8802-2 connectionless operations: Type 3 (acknowledged) and Type 1 (unacknowledged).

5.3.3.2 Type 2 operation. With Type 2 operation, a data-link connection shall be established between two systems prior to any exchange of information bearing PDUs. For efficiency at system startup, connections may be assumed to exist with all other stations in the network; and the system may depend on information transfer phase procedures to resolve error conditions. To guarantee a reliable (i.e., no loss) service, connections should be explicitly established, not assumed to exist. The connection normally shall remain open until a station leaves the net. The normal communications cycle between Type 2 systems shall consist of transferring PDUs from the source to the destination, and acknowledging receipt of these PDUs in the opposite direction.

5.3.3.3 Type 3 operation. For the purpose of this protocol, Type 3 operation is included in Type 1 operation.

5.3.3.4 Type 4 operation. With Type 4 operation, acknowledgments are decoupled from the original Decoupled Information Acknowledgment (DIA) PDU, and DIA PDUs contain a non-modulus identification number assigned by the originator.

5.3.3.5 Station class. Four station classes define the data link procedures supported by a system:

Station Class A - Supports Types 1 and 3; not Types 2 and 4
Station Class B - Supports Types 1, 2 and 3; not Type 4
Station Class C - Supports Types 1, 3 and 4; not Type 2
Station Class D - Supports Types 1, 2, 3 and 4.

5.3.4 Data-link frame. The data-link frame shall be the basic protocol data unit (PDU) of the link layer. The transmission header is not a PDU.

5.3.4.1 Types of frames. Three types of frames convey data over the data-link: an unnumbered frame (U PDUs), an information frame (I PDUs) and a supervisory frame (S PDUs).

5.3.4.1.1 Unnumbered frame. The U PDUs shall be used for Type 1, Type 2 and Type 4 operations. They provide connectionless information transfer for Types 1 and 4 operations. PDUs provide acknowledgment, and station identification/status information for Type 1 operations. They also provide data-link control functions for Type 1 through 4 operations.

5.3.4.1.2 Information frame. The I PDUs are used for information transfer in Type 2 operations only. They convey user data or message traffic across a link. The I PDUs are not used in Type 1 or Type 4 operations.

5.3.4.1.3 Supervisory frame. The S PDUs are optional and are used for data-link supervisory control functions and to acknowledge received I PDUs in Type 2 operations. Additionally, the Type 4 Decoupled Receive Ready (DRR) response S PDU is used to acknowledge Type 4 DIA PDUs. The S PDUs are not used in Type 1 operations.

5.3.4.2 Data-link frame structure. The basic elements of the data-link frame shall be the opening flag sequence, the address field, the control field, the information field, the FCS, and the closing flag sequence. Each Type 1, Type 2 and Type 4 data-link frame shall be structured as shown in the data link frame portion of Figure 11.

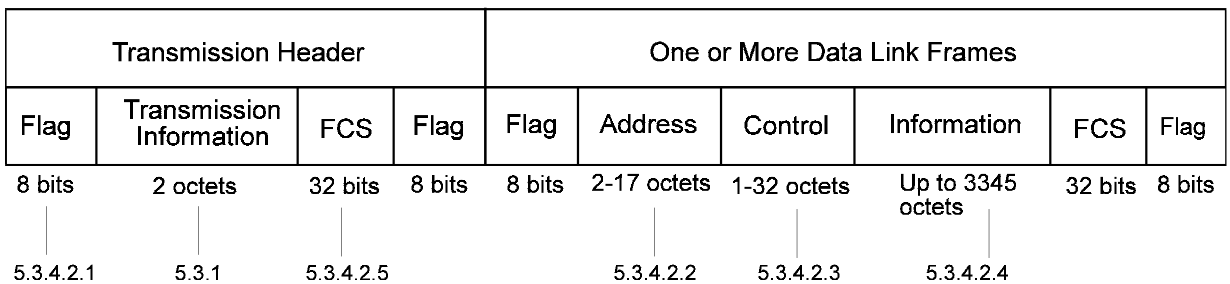



FIGURE 11. Data link frame structure and placement.

5.3.4.2.1 Flag sequence. All frames shall start and end with the 8-bit flag sequence of one 0 bit, six 1 bits, and one 0 bit (01111110). The flag shall be used for data-link frame synchronization.

5.3.4.2.2 Address fields. These fields shall identify the link addresses of the source and destinations.

5.3.4.2.2.1 Address format. Each address in the address fields shall consist of a single octet. The source address octet shall consist of a command/response (C/R) designation bit [the least significant bit (LSB)] followed by a 7-bit address representing the source. Each destination octet shall consist of an extension bit (the LSB) followed by the 7-bit destination address. The destination address uses a modification of the High-Level Data-link Control (HDLC) extended addressing format. The destination address shall be extended by setting the extension bit of a destination address octet to 0, indicating that the following octet is another destination address. The destination address field shall be terminated by an octet that has the extension bit set to 1. The destination address field shall be extendible from 1 address octet to 16 address octets. The format of the address fields shall be as shown in Figure 12.

5.3.4.2.2.2 Addressing convention. The following addressing conventions shall be implemented in the 7 address bits of each address octet. Address allocations, as shown in Figure 13, are divided among five address types: individual, group, global, special, and reserved.

NOTE: Source and destination addresses are assigned by an administrative authority.

5.3.4.2.2.2.1 Source and destination.

5.3.4.2.2.2.1.1 Source address. The source address is either an individual or special (Net Control or Net Entry) address and is always the first address. Its legal values range from 1 to 95. The source address has two parts: the C/R designation bit (bit 1, LSB) and the actual 7-bit address value. The C/R designation bit shall be set to 0 for commands and 1 for responses.

| LSB | | | | | | | MSB | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 0/1 | X | X | X | X | X | X | X | SOURCE Octet (1 = response; 0 = command) |
| 0 | X | X | X | X | X | X | X | DESTINATION 1 Octet |
| . | .. | | | | | | | |
| . | .. | | | | | | | |
| . | .. | | | | | | | |
| 1 | X | X | X | X | X | X | X | DESTINATION M Octet where M $\leq$ 16 |

FIGURE 12. Extended address field format.

| LSB | | | | | | | MSB | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 127 | Global Multicast Address |
| X | X | X | X | X | X | 1 | 1 | 96-126 | Group Multicast Addresses |
| X | X | X | X | X | X | X | X | 4-95 | Individual Addresses |
| X | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | Special (Immediate Retransmission) |
| X | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | Special (Net Control) Address |
| X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | Special (Net Entry) Address |
| X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Reserved Address |

FIGURE 13. Address allocation.

5.3.4.2.2.2.1.2 Destination address(es). The second through seventeenth address bytes are labeled destination addresses, which may be global, group, individual, or special addresses. Each destination address is contained in an 8-bit field, which has two parts: the extension bit (bit 1, LSB) and the actual 7-bit address value. An extension bit set to 0 indicates that 1 or more addresses follow. An extension bit set to 1 indicates the last address of the address string has been reached.

5.3.4.2.2.2.2 Types of addresses. The following paragraphs describe the five types of addresses and how they shall be used.

5.3.4.2.2.2.2.1 Reserved address. Address 0 is labeled a reserved address. A station receiving a value of 0 in the destination address field shall ignore the address and continue processing any remaining addresses.

5.3.4.2.2.2.2.2 Special addresses. Addresses 1, 2 and 3 are labeled special addresses. Addresses 1 and 2 are provided as network control and unit entry addresses for units entering a new network without knowledge of actual addresses being used. These special addresses are used as described in Appendix E (E5.1). The special address 3 is used for Type 1 acknowledged transmissions which require an immediate retransmission capability.

5.3.4.2.2.2.2.3 Individual addresses. Individual addresses uniquely identify a single station on a broadcast subnetwork. Individual addresses shall be assigned within the address range 4 to 95. Stations shall be capable of sending and receiving 1 to 16 individual destination addresses in a single data-link frame. Sending stations shall not use any individual address more than once in a data link frame. When individual address(es) are present, a receiving station shall receive all addresses, search for its unique individual address, and follow the media access procedures described in Appendix C.

5.3.4.2.2.2.2.4 Group multicast addresses. Group multicast addressing, used when broadcasting messages to multiple (but not all) stations on a broadcast subnetwork, may be implemented. The valid address range shall be 96 to 126. Assignment of membership to (or deletion from) a group is outside the scope of this protocol. While the use of link group multicast addresses is optional, all stations shall be capable of recognizing received group addresses. If a receiving station does not implement group addressing procedures, it shall still process all received addresses, but ignore the group addresses (that is, recognize range 96 to 126 as group addresses). When group addressing is implemented, a station shall be capable of sending and receiving 1 to 16 destination group addresses. Coupled data link acknowledgment of group multicast addresses using the F-bit shall not be allowed. An uncoupled TEST response PDU with its F-bit set to zero shall be sent in response to a TEST command PDU addressed to a group multicast address when the receiving station is a member of the specified group.

5.3.4.2.2.2.2.5 Individual, special and multicast addresses mixed. A station that optionally implements multicast (group and global) addressing shall also be capable of sending and receiving multicast, special and individual addresses "mixed" in a destination address subfield. All stations shall be capable of receiving mixed addresses. The reception and acknowledgment procedures stated in this paragraph shall be valid even for stations that do not implement multicast addressing procedures.

a. The total number of destination addresses shall not exceed 16.

b. Individual and special addresses may be mixed in any order.

c. All individual and special addresses shall precede multicast addresses.

d. The special address 3, if used, shall follow all individual, reserved, and other special addresses. It may precede group or global addresses, but shall not precede individual, reserved or other special addresses.

e. Only one type of multicast (group or global) shall be mixed in a destination address subfield.

f. If multicast, special and individual addresses are mixed, only the individual and special addresses are acknowledged when indicated.

g. Multicast addresses shall not be acknowledged but a data link response (using a TEST Response PDU) is allowed in the case where a TEST message is received with a multicast address in the destination field and the poll bit is set to 0.

h. A station that optionally implements multicast (group and global) addressing shall also be capable of sending and receiving multicast, special and individual addresses "mixed" in a destination subfield.

5.3.4.2.2.2.2.6 Global multicast addressing. Global multicast addressing, used when broadcasting messages to all systems on a broadcast subnetwork, shall be implemented through the unique bit pattern 1111111 (127). If the global address is used, it shall be the only multicast destination address, but individual addresses are allowed with the global address. All broadcast stations shall be capable of receiving and sending this address, and all stations will process the information contained within the frame. Data-link acknowledgment of the global address shall not be allowed, although the TEST response PDU is allowed in the case where a TEST message is received with the global address in the destination field and the poll bit is set to 0. Coupled data link acknowledgment of the global address using the F-bit shall not be allowed. An uncoupled TEST response PDU with its F-bit set to zero shall be sent in response to a TEST command PDU addressed to the global address.

5.3.4.2.2.3 Mapping. A link address is a point of attachment to a broadcast network. The upper-layer protocol is responsible for mapping one or more upper-layer addresses to a data-link address. Multiple upper-layer addresses may map to one or more group or individual addresses.

5.3.4.2.3 Control field. The control field indicates the type of PDU and the response requirements and connection information about the PDU being transmitted over the data link. A summary of the formats and bit patterns (showing LSB as the left most bit) for Types 1, 2 and 4 is shown in Tables VI, VII and VIII, respectively. Figure 14 illustrates the data-link PDU control field formats.

TABLE VI. Type 1 PDU formats.

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| UI COMMAND PDU ACKNOWLEDGMENT REQUIRED | Contains the source address and up to 16 individual, special, group or global link addresses of agencies for which the message is intended. | Bit pattern = 11001000 identifies this frame as a UI PDU requiring acknowledgment. | Contains data from the upper protocol layer. |
| ACKNOWLEDGMENT NOT REQUIRED | Contains the source address and up to 16 destination (individual, special, group and/or global mixed) addresses of agencies for which the message is intended. | Bit pattern = 11000000 identifies this frame as a UI PDU not requiring acknowledgment. | Contains data from the upper protocol layer. |
| Status PDU | | | |
| UNNUMBERED RECEIVE READY (URR) COMMAND | Contains source address, and individual, group, or global addresses. | Bit pattern = 11000100 indicating receive ready command. | No information field allowed. |
| UNNUMBERED RECEIVE READY (URR) RESPONSE | Contains source address and the address contained in the source subfield of a received UI PDU, which this frame acknowledges. | Bit pattern = 11001100 indicating last UI PDU is acknowledged. | No information field allowed. |
| UNNUMBERED RECEIVE NOT READY (URNR) COMMAND | Contains source address and individual, group, or global addresses of agencies that are to stop transmitting I and UI PDUs to the agency generating this frame. | Bit pattern = 11010000 indicating receive not ready command. | No information field allowed. |
| UNNUMBERED RECEIVE NOT READY (URNR) RESPONSE | Contains source address and destination to which this response is being sent. | Bit pattern = 11011000 indicating receive not ready response. | No information field allowed. |
| TEST COMMAND | Contains source address and the individual, group, or global address of agencies that are to respond. | Bit pattern = 1100X111 | Information field optional. |
| TEST RESPONSE | Contains source address and destination to which this response is being sent. | Bit pattern = 1100X111 | Information field optional. |

TABLE VII. Type 2 PDU formats.

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| U PDUs | | | |
| UNNUMBERED ACKNOWLEDGMENT (UA) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1100X110 | No information field allowed. |
| SET ASYNCHRONOUS BALANCED MODE EXTENDED (SABME) COMMAND | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1111X100 | No information field allowed. |
| RESET (RSET) COMMAND | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1111X001 | No information field allowed. |
| FRAME REJECT (FRMR) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1110X001 | See Figure 19. |
| DISCONNECT MODE (DM) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1111X000 | No information field allowed. |
| DISCONNECT (DISC) COMMAND | Contains source address and up to 16 individual destination addresses. | Bit pattern = 1100X010 | No information field allowed. |
| I PDU | | | |
| ACKNOWLEDGMENT OR OTHER APPROPRIATE RESPONSE REQUIRED | Contains source address and up to 16 individual and/or group or global addresses of agencies for which the message is intended. | Bit pattern = 0SSSSSSSXRRRRRRR. Identifies this frame as an I PDU. | Contains data from the upper layer protocol. |

TABLE VII. Type 2 PDU formats (Continued).

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| S PDUs | | | |
| RECEIVE READY (RR) COMMAND | Contains source address and up to 16 individual addresses. | Bit pattern = 10000000XRRRRRRR, indicating receive ready command. | No information field allowed. |
| RECEIVE READY (RR) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10000000XRRRRRRR, indicating last I PDU is acknowledged. | No information field allowed. |
| RECEIVE NOT READY (RNR) COMMAND | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10100000XRRRRRRR, indicating receive not ready command. | No information field allowed. |
| RECEIVE NOT READY (RNR) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10100000XRRRRRRR, indicating receive not ready. | No information field allowed. |
| SELECTIVE REJECT (SREJ) COMMAND AND RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10110000XRRRRRRR. | No information field allowed. |
| REJECT (REJ) COMMAND AND RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10010000XRRRRRRR. | No information field allowed. |

(X represents the P/F bit setting, S represents send sequence number, and R represents receive sequence number.)

TABLE VIII. Type 4 PDU formats.

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| U PDUs | | Bit pattern - | |
| DIA ACK Req'd | Contains source address and up to 16 individual and/or group or global link addresses for which the message is intended. | 110101LL<-ID #-><br><br>L-bits are used to indicate PDU precedence | Contains data from the upper layer protocol. |
| S PDU | | | |
| DRR resp | Contains source address and individual address for the originator of the DIA PDU which this PDU ACKs. | 100010LL<-ID #-><br>L-bits are used to indicate precedence of PDU being ACK'd. The ID no. is that of the DIA PDU being ACK'd. | No information field allowed |
| DRR cmd | Contains source address and individual, group or global address | 1000100000000000 indicates a station is ready to receive DIA PDUs. | No information field allowed |
| DRNR resp | Contains source address and individual address for the originator of the DIA PDU, which this PDU acknowledges | 101010LL<-ID #-> indicates a station is not ready to receive DIA PDUs due to a busy condition.<br>L-bits are used to indicate precedence of PDU being ACK'd. The ID no. is that of the DIA PDU being ACK'd. | No information field allowed |
| DRNR cmd | Contains source address and individual, group or global address | 1010100000000000 indicates a station is not ready to receive DIA PDUs due to a busy condition. | No information field allowed |

| | | LSB 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | MSB 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INFORMATION TRANSFER | Type 2 | 0 | N(S) | | | | | | | P/F | N(R) | | | | | | |
| SUPERVISORY COMMANDS/RESPONSES (S PDUs) | Type 2 | 1 | 0 | S | S | Z | Z | Z | Z | P/F | N(R) | | | | | | |
| | Type 4 | 1 | 1 | S | S | 1 | 0 | L | L | ID Number | | | | | | | |
| UNNUMBERED COMMANDS/RESPONSES (U PDUs) | Types 1 & 2 | 1 | 1 | M | M | P/F | M | M | M | | | | | | | | |
| | Type 4 | 1 | 1 | 0 | 1 | 0 | 1 | L | L | ID Number | | | | | | | |

<u>Notes</u>:

The left-most bit is the first bit delivered to and received from the physical layer.

N(S) = Transmitter send sequence number (Bit 2 = LSB)
N(R) = Transmitter receive sequence number (Bit 10 = LSB)
S = Supervisory Function bit
M = Modifier function bit
Z = Reserved and set to zero
P/F = Poll bit - command PDU transmissions
Final bit - response PDU transmissions
(1 = Poll/Final)
L = Level of precedence (LSB on left)
1 1 = reserved (value = 3)
0 1 = routine (value = 2)
1 0 = priority (value = 1)
0 0 = urgent (value = 0)

FIGURE 14. <u>Data-link PDU control field formats</u>.

5.3.4.2.3.1 <u>Type 1 operations</u>. For Type 1 operations, the control field is an 8-bit pattern designating 1 of 5 types of U PDUs. The URR and URNR PDUs are used to indicate overall station status.

5.3.4.2.3.2 <u>Type 2 operations</u>. The Type 2 control field is a 16-bit pattern for I PDUs and S PDUs and includes sequence numbers. The Type 2 U PDUs have an 8-bit pattern. The Type 2 control field shall be repeated if more than one destination address is present. Each destination address field shall have a corresponding control field. Each of the corresponding control fields (when repeated) shall be identical except for the P/F bit and sequence numbers. The Type 1

Unnumbered Receive Ready (URR) and Unnumbered Receive Not Ready (URNR) PDUs are used to indicate overall station status. The RR and RNR are used to indicate station status for Type 2 operations only.

5.3.4.2.3.3 Type 4 operations. The Type 4 control field is a 16-bit pattern for U PDUs and S PDUs, and includes identification numbers. The control field distinguishes between a DIA PDU with a frame identification number and four S PDUs used in a connectionless environment with decoupled acknowledgments. The Type 1 URR and URNR are used to indicate overall station status. The DRR and Decoupled Receive Not Ready (DRNR) PDUs are used to indicate station status for Type 4 operations only.

5.3.4.2.3.4 Poll/final bit. The Poll/final (P/F) bit serves a function in both command and response PDUs. In command PDUs, the P/F bit is referred to as the P-bit. In response PDUs, it is referred to as the F-bit. The P-bit set to 1 shall be used to solicit a response PDU, with the F-bit set to 1. On a data link, at most one Type 1 PDU and one Type 2 PDU with P-bit set to 1 shall be outstanding in a given direction at a given time. Before a station issues another PDU with the P-bit set to 1 to a particular destination, it shall have received a response PDU from that remote station with the F-bit set to 1 or have timed out waiting for that response PDU. The P/F bit is not implemented in Type 4 operations.

5.3.4.2.3.5 Sequence numbers. Sequence numbers are used only with Type 2 I and S PDUs. The Type 2 I and S PDUs shall contain sequence numbers. The sequence numbers shall be in the range of 0-127.

5.3.4.2.3.6 Identification numbers. Identification numbers are used only with Type 4 DIA PDUs and DRR/DRNR S PDUs. The Type 4 DIA and DRR/DRNR response S PDUs shall contain an identification number. The identification number is used to identify each DIA PDU and permit decoupled acknowledgments in a connectionless environment. The identification numbers shall be in the range of 1-255.

5.3.4.2.3.7 Precedence. The two level-of-precedence bits (L-bits) are used only in the control field of Type 4 PDUs. In the DIA PDU, the L-bits indicate the precedence of the data in the information field. In the DRR response S PDU, the L-bits are used to indicate the precedence of the DIA PDU information being acknowledged. The data link precedence values and their appropriate mappings to network layer precedence levels are indicated in 5.3.16.

5.3.4.2.4 Information field. The information field may be present in either the I, UI, DIA, FRMR or TEST PDU. The length of the information field shall be a multiple of 8 bits, not to exceed 3345 octets. If the data is not a multiple of 8 bits, 1 to 7 fill bits (0) shall be added to meet this requirement. The maximum information field size defaults to 3345 octets. A smaller size may be established at initialization through local system information or using the XNP messages (see Appendix E). Contents of the information fields of the FRMR and TEST PDUs are described in 5.3.6.2.3.6 and 5.3.6.1.5, respectively.

5.3.4.2.5 Frame check sequence. For error detection, all frames shall include a 32-bit FCS prior to the closing flag sequence. The contents of the address, control, and information fields are included in the FCS calculation. Excluded from the FCS calculation are the 0's inserted by the 0-bit insertion algorithm. The formula for calculating the FCS, which is the 1's complement (inversion) of the remainder of a modulo-2 division process, employs the generator polynomial, P(X), having the form

$$P(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$$

FCS generation shall be in accordance with the paragraph entitled "32-bit Frame Checking Sequence" in ISO 3309, and implemented in a manner that provides a unique remainder when a frame is received without bit errors incurred during transmission. If the FCS of a received frame proves the frame to be invalid, the frame shall be discarded.

5.3.4.3 Data-link PDU construction. The data-link procedures that affect data-link PDU construction include (a) order-of-bit transmission and 0-bit insertion, discussed below; and (b) FEC and TDC, discussed in 5.3.14.

5.3.4.3.1 Order-of-bit transmission. The order-of-bit transmission function specifies the sequence in which bits are ordered by the data-link layer for transmission by the physical layer. The Information Field and control field(s) shall be transmitted LSB of each octet first. The flag shall be transmitted LSB first. For the FCS, the most significant bit (MSB) shall be transmitted first. For the address field, the source address octet is transmitted first and the destination address octet(s) are transmitted in order. The LSB of each address octet is transmitted first. The information field octets shall be transmitted in the same order as received from the upper layers, LSB of each octet first.

5.3.4.3.2 Zero-bit insertion algorithm. The occurrence of a spurious flag sequence within a frame or Transmission Header shall be prevented by employing a 0-bit insertion algorithm. After the entire frame has been constructed, the transmitter shall always insert a 0 bit after the appearance of five 1's in the frame (with the exception of the flag fields). After detection of an opening flag sequence, the receiver shall search for a pattern of five 1's. When the pattern of five 1's appears, the sixth bit shall be examined. If the sixth bit is a 0, the 5 bits shall be passed as data, and the 0 shall be deleted. If the sixth bit is a 1, the receiver shall inspect the seventh bit. If the seventh bit is a 0, a flag sequence has been received. If the seventh bit is a 1, an invalid message has been received and should be discarded.

5.3.5 Operational parameters. The various parameters associated with the control field formats are described in the following sections.

5.3.5.1 Type 1 operational parameters. The only parameter that exists in Type 1 operation is the P/F bit. The Poll (P) bit set to 1 shall be used to solicit (poll) an immediate correspondent response PDU with the Final (F) bit set to 1 from the addressed station. The response with F-bit set to 1 shall be transmitted in accordance with the response hold delay (RHD) procedures defined in Appendix C (C4.2).

5.3.5.2 Type 2 operational parameters. The various parameters associated with the control field formats in Type 2 operation are described in 5.3.5.2.1 to 5.3.5.2.3.2.

5.3.5.2.1 Modulus. Each I PDU shall be sequentially numbered with a numeric value between 0 and MODULUS minus ONE (where MODULUS is the modulus of the sequence numbers). MODULUS shall equal 128 for the Type 2 control field format. The sequence numbers shall cycle through the entire range. The maximum number of sequentially numbered I PDUs that may be outstanding (that is, unacknowledged) in a given direction of a data-link connection at any given time shall never exceed one less than the modulus of the sequence numbers. This restriction shall prevent any ambiguity in the association of sent I PDUs with sequence numbers during normal operation and error recovery action.

5.3.5.2.2 PDU-state variables and sequence numbers. A station shall maintain a send-state variable, V(S), for the I PDUs it sends and a receive-state variable, V(R), for the I PDUs it receives on each data-link connection. The operation of V(S) shall be independent of the operation of V(R).

5.3.5.2.2.1 Send-state variable V(S). The V(S) shall denote the sequence number of the next in-sequence I PDU to be sent on a specific data-link connection. The V(S) shall take on a value between 0 and MODULUS minus ONE. The value of V(S) shall be incremented by one with each successive I PDU transmission on the associated data-link connection, but shall not exceed receive sequence number N(R) of the last received PDU by more than MODULUS minus ONE.

5.3.5.2.2.2 Send-sequence number N(S). Only I PDUs shall contain N(S), the send sequence number of the sent PDU. Prior to sending an I PDU, the value of N(S) shall be set equal to the value of the V(S) for that data-link connection.

5.3.5.2.2.3 Receive-state variable V(R). The V(R) shall denote the sequence number of the next in-sequence I PDU to be received on a specific data-link connection. The V(R) shall take on a value between 0 and MODULUS minus ONE. The value of the V(R) associated with a specific data-link connection shall be incremented by one whenever an error-free I PDU is received whose N(S) equals the value of the V(R) for the data-link connection.

5.3.5.2.2.4 Receive sequence number N(R). All I and S PDUs shall contain N(R), the expected sequence number of the next received I PDU on the specified data-link connection. Prior to sending an I or S PDU, the value of N(R) shall be set equal to the current value of the associated V(R) for that data-link connection. N(R) shall indicate that the station sending the N(R) has received correctly all I PDUs numbered up through N(R)-1 on the specified data-link connection.

5.3.5.2.3 Poll/final (P/F) bit. The P/F bit shall serve a function in Type 2 operation in both command and response PDUs. In command PDUs the P/F bit shall be referred to as the P-bit. In response PDUs it shall be referred to as the F-bit. P/F bit exchange provides a distinct C/R linkage that is useful during both normal operation and recovery situations.

5.3.5.2.3.1 Poll-bit functions. A command PDU with the P-bit set to 1 shall be used to solicit (poll) a response PDU with the F-bit set to 1 from the addressed station on a data-link connection. Only one Type 2 PDU with a P-bit set to 1 shall be outstanding in a given direction at a given time on the data-link connection between any specified pair of stations. Before a station issues another PDU on the same data-link connection with the P-bit set to 1, the station shall have received a response PDU with the F-bit set to 1 from the addressed station. If no valid response PDU is received within a system-defined P-bit timer time-out period, the resending of a command PDU with the P-bit set to 1 shall be permitted for error recovery purposes.

5.3.5.2.3.2 Final-bit functions. The F-bit set to 1 shall be used to respond to a command PDU with the P-bit set to 1. Following the receipt of a command PDU with the P-bit set to 1, the station shall send a response PDU with the F-bit set to 1 on the appropriate data-link connection at the first possible opportunity. First possible opportunity is defined as transmitting the frame ahead of other frames at the next network access opportunity. The response PDU shall be assigned an URGENT precedence. The station shall be permitted to send appropriate response PDUs with the F-bit set to 0 at any net access opportunity without the need for a command PDU.

5.3.5.3 Type 4 operational parameters. The two parameters associated with the control field formats in Type 4 operation are precedence described in 5.3.4.2.3.7 and Identification number.

5.3.5.3.1 Identification number. The Identification number field is used in conjunction with the originator's station address to identify the PDU. The station's identification number is assigned just prior to the initial transmission of the PDU. This number is not changed on link layer retransmission of the PDU. Each station shall keep a number for originating PDUs. Duplicate frame identification numbers from the same originator shall not be used for more than one outstanding (unacknowledged) DIA PDU.

5.3.6 Commands and responses. This section defines the commands and associated responses. Definitions of the set of commands and responses for each of the control field formats for Type 1, Type 2 and Type 4 operations, respectively, are contained in 5.3.6.1, 5.3.6.2 and 5.3.6.3. The C/R bit, the LSB of the source address field, is used to distinguish between commands and responses. The following discussion of commands and responses assumes that the C/R bit has been properly decoded. A single multi-addressed frame shall not contain different PDU types nor contain the same individual address more than once. The control field for all addresses in a single multi-addressed frame shall be the same except for the P/F bit and sequence number. Some of the commands described in the following paragraphs require a response at the earliest opportunity. Response PDUs requiring "earliest opportunity" transmission shall be queued ahead of all other PDUs, except those queued for "first possible opportunity" for transmission during the next network access opportunity. The response PDU shall assume the precedence level of the highest PDU queued or the mid (PRIORITY) level, whichever is greater. The Type 4 DRR response PDU shall assume the precedence of the DIA frame it is acknowledging.

5.3.6.1 Type 1 operation commands and responses. Type 1 commands and responses are all U PDUs. The U PDU encodings for Type 1 operations are listed in Figure 15.

| FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Bit Position |
| 1 | 1 | 0 | 0 | P | 0 | 0 | 0 | UI Command |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | URR Command |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | URR Response |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | URNR Command |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | URNR Response |
| 1 | 1 | 0 | 0 | P/F | 1 | 1 | 1 | Test Command/Response |

FIGURE 15. Type 1 operation control-field bit assignments.

5.3.6.1.1 Unnumbered information command. The unnumbered information PDU (UI PDU) shall be used to send information to one or more stations. The P-bit of the control field of the UI PDU is used by the transmitter to request that individually addressed receiver(s) acknowledge receipt of the transmitted UI PDU or to specify that an acknowledgment is not required. The UI PDU shall be addressed to individual, special, group, or global addresses. The source address shall be the individual address of the transmitting station.

5.3.6.1.2 Unnumbered receive-ready command. The unnumbered receive-ready (URR) command PDU shall be transmitted to one or more stations to indicate that the sending station is ready to receive I, DIA and UI PDUs. The URR PDU shall be addressed to individual, group, or global addresses. The source address shall be the individual address of the transmitting station.

5.3.6.1.3 Unnumbered receive-not-ready command. The unnumbered receive-not-ready (URNR) command PDU shall be transmitted to one or more stations to indicate that the sending station is busy and cannot receive I, DIA or UI PDUs. The URNR PDU shall be addressed to individual, group, or global addresses. The source address shall be the individual address of the transmitting station.

5.3.6.1.4 Test command. The test command (TEST) shall be used to cause the destination station to respond with the TEST response at the earliest opportunity, thus performing a basic test of the transmission path. An information field is optional with the TEST command PDU. It may contain any bit pattern, but is limited to a maximum length of 128 octets. If present, however, the received information field shall be returned, if possible, by the addressed station in the TEST response PDU. The TEST command, with the P-bit set to 1, shall cause the individually addressed destination station(s) to respond with a TEST response PDU (with no information field), with the F-bit set to 1, after the appropriate RHD period (see C4.2). The TEST command, with the P-bit set to 0 shall cause each destination station (including members of group and global addresses) to respond with a TEST response (with information field) with the F-bit set to 0 at the earliest opportunity. Group and global addressees do not reply to a TEST command with the P-bit set to 1. The TEST command PDU shall be addressed to an individual and/or group or global destination addresses. The source address shall be an individual address.

5.3.6.1.6 Unnumbered receive-ready response. The URR response shall be used to acknowledge a UI command that requested an acknowledgment (P-bit set to 1). The URR response shall be the first PDU sent by the receiving station upon receiving a UI command after the appropriate RHD period (see C4.2). The source and destination shall be individual addresses.

5.3.6.1.7 Test response. The TEST response, with F-bit set to 1, without an information field shall be used by individual addressees to reply to the TEST command with the P-bit set to 1. The TEST response shall be the first PDU sent by the receiving station upon receiving a TEST command PDU, after the appropriate RHD period (see C4.2). Group and global addressees do not reply to TEST command with P-bit set to 1. The TEST response, with F-bit set to 0, shall be used by all addressees (individual, group and global) to reply to the TEST command with the P-bit set to 0 at the earliest opportunity. If an information field was present in the TEST command PDU that had the P-bit set to 0, the TEST response PDU shall contain the same information field contents. If the station cannot accept the information field of the TEST command, a TEST response without an information field may be returned. The source and destination addresses shall be an individual address.

5.3.6.1.9 Unnumbered receive-not-ready response. The URNR response PDU shall be used to reply to a UI command with the P-bit set to 1, if the UI command cannot be processed due to a busy condition. The URNR response PDU does not contain any acknowledgment information. If used, the URNR response shall be the first PDU transmitted by the receiving station, upon receiving a UI command, after the appropriate RHD period (see C4.2). The URNR response shall have the F-bit set to 1 and shall be addressed to the source of the UI command.

5.3.6.2 Type 2 operation commands and responses. Type 2 commands and responses consist of I, S, and U PDUs.

5.3.6.2.1 Information-transfer-format command and response. The function of the information (I) command and response shall be to transfer sequentially numbered PDUs that contain an information field across a data-link connection. Send and receive sequence numbers associated with group and global addresses shall be set to zero by the transmitter and ignored by the receiver and are not acknowledged. The encoding of the I PDU control field for Type 2 operation shall be as listed in Figure 16.

The I PDU control field shall contain two sequence number subfields: N(S), which shall indicate the sequence number associated with the I PDU; and N(R), which shall indicate the sequence number (as of the time the PDU is sent) of the next expected I PDU to be received, and, consequently, shall indicate that the I PDUs numbered up through N(R)-1 have been received correctly.

| FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER<br>↓ | | | |
|---|---|---|---|
| 1 | 2 3 4 5 6 7 8 | 9 | 10 11 12 13 14 15 16 |
| 0 | N(S) | P/F | N(R) |
| INFORMATION TRANSFER FORMAT | SEND SEQUENCE NUMBER (0-127) | COMMAND (POLL) RESPONSE (FINAL) | RECEIVE SEQUENCE NUMBER (0-127) |

FIGURE 16. Information-transfer-format control field bits.

5.3.6.2.2 Supervisory-format commands and responses. Supervisory (S) PDUs shall be used to perform numbered supervisory functions such as acknowledgments, temporary suspension of information transfer, or error recovery. S PDUs shall not contain an information field and, therefore, shall not increment the send-state variable at the sender or the receive-state variable at the receiver. Encoding of the S PDU control field for Type 2 operation shall be as shown in Figure 17. An S PDU shall contain an N(R), which shall indicate, at the time of sending, the sequence number of the next expected I PDU to be received. This shall acknowledge that all I PDUs numbered up through N(R)-1 have been received correctly, except in the case of the selective reject (SREJ) PDU. The use of N(R) in the SREJ PDU is explained in 5.3.6.2.2.4.

| FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER<br>↓ | | | | |
|---|---|---|---|---|
| 12 | 3 4 | 5 6 7 8 | 9 | 10 11 12 13 14 15 16 |
| 10 | S S | X X X X | P/F | N(R) |
| | | \-----------------------/ | | \-----------------------/ |
| ↓ | ↓ | ↓ | ↓ | ↓ |
| SUPER-VISORY FORMAT | | RESERVED SET TO 0 | COMMAND (POLL) RESPONSE (FINAL) | RECEIVE SEQUENCE NUMBER (0-127) |

| COMMANDS | SS | RESPONSES |
|---|---|---|
| RECEIVE READY (RR) | 00 | RECEIVE READY (RR) |
| REJECT (REJ) | 01 | REJECT (REJ) |
| RECEIVE NOT READY (RNR) | 10 | RECEIVE NOT READY (RNR) |
| SELECTIVE REJECT (SREJ) | 11 | SELECTIVE REJECT (SREJ) |

FIGURE 17. Supervisory-format control field bits.

5.3.6.2.2.1 Receive-ready (RR) command and response. The RR PDU shall be used by a station to indicate it is ready to receive I PDUs. I PDUs numbered up through N(R)-1 shall be considered as acknowledged.

5.3.6.2.2.2 Reject (REJ) command and response. The REJ PDU shall be used by a station to request the resending of I PDUs, starting with the PDU numbered N(R). I PDUs numbered up through N(R)-1 shall be considered as acknowledged. It shall be possible to send additional I PDUs awaiting initial sending after the resent I PDUs. With respect to each direction of sending on a data-link connection, only one "sent REJ" condition shall be established at any given time. The "sent REJ" condition shall be cleared upon receipt of an I PDU with an N(S) equal to the N(R) of the REJ PDU. The "sent REJ" condition may be reset in accordance with procedures described in 5.3.7.2.5.4. Receipt of a REJ PDU shall indicate the clearance of a busy condition except as noted in 5.3.7.2.5.8.

5.3.6.2.2.3 Receive-not-ready (RNR) command and response. The RNR PDU shall be used by a station to indicate a busy condition (a temporary inability to accept subsequent I PDUs). I PDUs numbered up through N(R)-1 shall be considered as acknowledged. I PDUs numbered N(R) and any subsequent I PDUs received shall not be considered as acknowledged; the acceptance status of these PDUs shall be indicated in subsequent exchanges.

5.3.6.2.2.4 Selective-reject (SREJ) command and response. The selective reject PDU is used by a station to request retransmission of the single I PDU numbered N(R). If the P-bit in the SREJ PDU is set to 1, then I PDUs numbered up to N(R)-1 shall be considered acknowledged. If the P-bit is set to 0, then the N(R) of the SREJ PDU does not indicate acknowledgment of any I PDUs. Each SREJ exception condition shall be cleared (reset) upon receipt of an I PDU with an N(S) equal to the N(R) of the SREJ PDU. A data station may transmit one or more SREJ PDUs, each containing a different N(R) with the P-bit set to 0, before one or more earlier SREJ exception conditions have been cleared. I PDUs that have been transmitted following the I PDU designated by the SREJ PDU shall not be retransmitted as the result of receiving the SREJ PDU. Additional I PDUs awaiting initial transmission may be transmitted following the retransmission of the specific I PDU requested by the SREJ PDU. The SREJ is used to recover from receipt of frames with various types of errors, including sequence number errors due to lost frames and FCS errors.

5.3.6.2.3 Unnumbered-format commands and responses. Unnumbered (U) commands and responses shall be used in Type 2 operations to extend the number of data-link connection control functions. The U PDUs shall not increment the state variables on the data-link connection at either the sending or the receiving station. Encoding of the U PDU control field shall be as in Figure 18.

5.3.6.2.3.1 Set asynchronous balanced mode extended (SABME) command. The SABME command PDU shall be used to establish a data-link connection to the destination station in the asynchronous balanced mode (ABM). No information shall be permitted with the SABME command PDU. The destination station shall confirm receipt of the SABME command PDU by sending a UA response PDU on that data-link connection at the earliest opportunity. Upon acceptance of the SABME command PDU, the destination station send- and receive-state variables shall be set to 0. If the UA response PDU is received correctly, then the initiating station shall also assume the asynchronous balanced mode with its corresponding send- and receive-state variables set to 0. Previously sent I PDUs that are unacknowledged when this command is executed shall remain unacknowledged. A station may resend the contents of the information field of unacknowledged outstanding I PDUs

| FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | P | 1 | 0 | 0 | SABME Command |
| 1 | 1 | 0 | 0 | P | 0 | 1 | 0 | DISC Command |
| 1 | 1 | 1 | 1 | P | 0 | 0 | 1 | RSET Command |
| 1 | 1 | 0 | 0 | F | 1 | 1 | 0 | UA Response |
| 1 | 1 | 1 | 1 | F | 0 | 0 | 0 | DM Response |
| 1 | 1 | 1 | 0 | F | 0 | 0 | 1 | FRMR Response |

FIGURE 18. Unnumbered-format control field bits.

5.3.6.2.3.2 Disconnect (DISC) command. The DISC command PDU shall be used to terminate an asynchronous balanced mode previously set by a SABME command PDU. It shall be used to inform the destination station that the source station is suspending operation of the data-link connection and the destination station should assume the logically disconnected mode. No information field shall be permitted with the DISC command PDU. Prior to executing the command, the destination station shall confirm the acceptance of the DISC command PDU by sending a UA response PDU on that data-link connection. Previously sent I PDUs that are unacknowledged when this command is executed shall remain unacknowledged.

5.3.6.2.3.3 Reset (RSET) command. The RSET command PDU shall be used by a station in an operational mode to reset the V(R) in the addressed station. No information field is permitted with the RSET command PDU. The addressed station shall confirm acceptance of the RSET command by transmitting a UA response PDU at the earliest opportunity. Upon acceptance of this command, the V(R) of the addressed station shall be set to 0. If the UA response PDU is received correctly, the initializing station shall reset its V(S) to 0.

5.3.6.2.3.4 Unnumbered acknowledgment (UA) response. The UA response PDU shall be used by a station on a data-link connection to acknowledge receipt and acceptance of the SABME, DISC, and RSET command PDUs. These received command PDUs shall not be executed until the UA response PDU is sent. No information field shall be permitted with the UA response PDU.

5.3.6.2.3.5 Disconnect mode (DM) response. The DM response PDU shall be used to report status indicating that the station is logically disconnected from the data-link connection and is in asynchronous disconnected mode (ADM). No information field shall be permitted with the DM response PDU.

5.3.6.2.3.6 Frame reject (FRMR) response. The FRMR response PDU shall be used by the station in the ABM to report that one of the following conditions, which is not correctable by resending the identical PDU, resulted from the receipt of a PDU from the remote station:

a. The receipt of a command PDU or a response PDU that is invalid or not implemented. Below are three examples of invalid PDUs:

(1) the receipt of an S or U PDU with an information field that is not permitted,
(2) the receipt of an unsolicited F-bit set to 1, and
(3) the receipt of an unexpected UA response PDU.

b. The receipt of an I PDU with an information field that exceeded the established maximum information field length that can be accommodated by the receiving station for that data-link connection.

c. The receipt of an invalid N(R) from the remote station. An invalid N(R) shall be defined as one that signifies an I PDU that has previously been sent and acknowledged, or one that signifies an I PDU that has not been sent and is not the next sequential I PDU waiting to be sent.

d. The receipt of an invalid N(S) from the remote station. An invalid N(S) shall be defined as an N(S) that is greater than or equal to the last sent N(R)+ k, where k is the maximum number of outstanding I PDUs. The parameter k is the window size indicated in the XNP message (see Appendix E).

The responding station shall send the FRMR response PDU at the earliest opportunity. An information field shall be returned with the FRMR response PDU to provide the reason for the PDU rejection. The information field shall contain the fields shown in Figure 19. The station receiving the FRMR response PDU shall be responsible for initiating the appropriate mode setting or resetting corrective action by initializing one or both directions of transmission on the data-link connection, using the SABME, RSET or DISC command PDUs, as applicable.

5.3.6.3 Type 4 operation commands and responses. The Type 4 commands and responses consist of U and S PDUs.

5.3.6.3.1 Unnumbered information transfer format commands. The function of the Type 4 unnumbered information with decoupled acknowledgment (DIA) commands shall be to transfer PDUs that contain an identification number and an information field across a connectionless link. The encoding of the PDU control field for Type 4 operation shall be as listed in Figure 20.

| FIRST CONTROL BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | | | | | |
|---|---|---|---|---|---|---|
| 1----------16 | 17 | 18--24 | 25 | 26--32 | 33--36 | 37--40 |
| REJECTED PDU CONTROL FIELD | 0 | V(S) | C/R | V(R) | WXYZ | V000 |

FIGURE 19. FRMR information field format.

Notes to Figure 19:

a) Rejected PDU control field shall be the control field of the received PDU that caused the FRMR exception condition on the data-link connection. When the rejected PDU is a U PDU, the control field of the rejected PDU shall be positioned in bit positions 1-8, with 9-16 set to 0.

b) V(S) shall be the current send-state variable value for this data-link connection at the rejecting station (bit 18 = low-order bit).

c) C/R set to 1 shall indicate that the PDU causing the FRMR was a response PDU, and C/R set to 0 shall indicate that the PDU causing the FRMR was a command PDU.

d) V(R) shall be the current receive-state variable value for this data-link connection at the rejecting station (bit 26 = low-order bit).

e) W set to 1 shall indicate that the control field received and returned in bits 1 through 16 was invalid or not implemented. Examples of invalid PDU are defined as:

    (1) the receipt of an S or U PDU with an information field that is not permitted,
    (2) the receipt of an unsolicited F-bit set to 1, and
    (3) the receipt of an unexpected UA response PDU.

f) X set to 1 shall indicate that the control field received and returned in bits 1 through 16 was considered invalid because the PDU contained an information field that is not permitted with this command or response. Bit W shall be set to 1 in conjunction with this bit.

g) Y set to 1 shall indicate that the information field received exceeded the established maximum information field length which can be accommodated by the rejecting station on that data-link connection.

h) Z set to 1 shall indicate that the control field received and returned in bits 1 through 16 contained an invalid N(R).

i) V set to 1 shall indicate that the control field received and returned in bits 1 through 16 contained an invalid N(S). Bit W shall be set to 1 in conjunction with this bit.

| FIRST CONTROL BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | |
|---|---|---|
| PDU Identifier | L-bits | PDU Identification No. |
| 1 2 3 4 5 6 | 7 8 | 9 10 11 12 13 14 15 16 |
| 1 1 0 1 0 1 | L L | <---ID Number---> |

FIGURE 20. Type 4 DIA PDU control field bit assignments.

5.3.6.3.1.1 DIA PDU acknowledgment. Transmitted DIA PDUs are acknowledged by a Type 4 DRR response S PDU with the same precedence from the receiving stations, except for the following cases:

a. The receiving station is a global or group multicast addressee only.

b. The receiving station's link address is not in the destination address field.

c. The response mode parameter is set to no.

5.3.6.3.2 Supervisory format commands and responses. The S PDUs shall be used to convey link acknowledgment of a DIA PDU and whether or not a station is ready to receive Type 4 PDUs. The S PDU has a single destination address. For the command DRR and DRNR S PDUs the destination address is the global address and does not acknowledge DIA PDUs. These S PDUs are used to indicate Type 4 receive status. The response DRR S PDU contains a single destination address, that of the originator of the DIA PDU being acknowledged. The command S PDU level of precedence shall be set to the highest precedence while response S PDUs shall use the precedence of the DIA PDU which they are acknowledging. The encoding of the S PDU control field for Type 4 operation shall be as listed in Figure 21.

5.3.7 Description of procedures by type. The procedures for each operation type are described in 5.3.7.1, 5.3.7.2 and 5.3.7.3 (and their subparagraphs). The three types of procedures can coexist on the same network.

5.3.7.1 Description of type 1 procedures. The procedures associated with Type 1 operation are described in 5.3.7.1 through 5.3.7.1.5.11.

5.3.7.1.1 Modes of operation. In Type 1 operation, no modes of operation are defined. A station using Type 1 procedures shall support the entire procedure set whenever it is operational on the network.

| FIRST CONTROL BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | |
|---|---|---|
| PDU Identifier | L-bits | PDU Identification No. |
| 1 2 3 4 5 6 | 7 8 | 9 10 11 12 13 14 15 16 |
| 1 0 0 0 1 0 | 0 0 | 0 0 0 0 0 0 0 0<br>DRR Command |
| 1 0 0 0 1 0 | L L | <---ID Number---><br>DRR Response |
| 1 0 1 0 1 0 | 0 0 | 0 0 0 0 0 0 0 0<br>DRNR Command |
| 1 0 1 0 1 0 | L L | <---ID Number---><br>DRNR Response |

FIGURE 21. Type 4 S PDU control field bit assignments.

5.3.7.1.2 Procedure for addressing. The address fields shall be used to indicate the source and destinations of the transmitted PDU. The first bit in the source address field shall be used to identify whether a command or a response is contained in the PDU. Individual, group, special, and global addressing shall be supported for destination addresses in command PDUs. The source address field shall contain an individual or special address.

5.3.7.1.3 Procedure for using the P/F bit. The station receiving a UI or TEST command PDU with the P-bit set to 1 shall send an appropriate response PDU with the F-bit set to 1.

5.3.7.1.4 Procedures for logical data-link set-up and disconnection. Type 1 operation does not require any prior data-link connection establishment (set-up), and hence no data-link disconnection. Once the service access point has been enabled within the station, information may be sent to, or received from, a remote station also participating in Type 1 operation.

5.3.7.1.5 Procedures for information transfer.

5.3.7.1.5.1 Sending UI command PDUs. Information transfer from an initiating station to a responding station shall be accomplished by sending the UI command PDU. When a sending station sends a UI command PDU with the P-bit set to 1, it shall start an acknowledgment timer for that transmission and initialize the internal transmission count variable to zero. If all expected URR or URNR response PDUs are not received before the timer runs out, the sending station shall resend the UI command PDU, increment the internal transmission count variable, and restart the acknowledgment timer. Prior to resending the UI command PDU, the group and global addresses shall be removed as well as individual and special addresses from which a response (URR or URNR) was received. The special address 3 shall not be removed prior to retransmission unless it is the only address remaining. No retransmission shall be attempted unless an individual or special address other than 3 remains. If a URR response PDU is still not received, this resending procedure shall be repeated until the value of the internal transmission count variable is equal to the value of the logical link parameter N4, as described in 5.3.8.1.1c, at which time a DL-Status-Indication shall be reported to the upper layer indicating an acknowledgment failure. An internal transmission count shall be maintained for each UI information exchange (where P-bit = 1) between a pair of sending and receiving stations. Both the acknowledgment timer and the internal transmission count, for that exchange, shall not affect the information exchange with other receiving stations. If a URNR response PDU is received in response to a UI command with the P-bit set to 1, the receiving station shall designate the sending station as busy. The retransmission of the UI command shall follow the rules for the busy condition. Transmission of UI commands to that station shall be discontinued until the busy state is cleared. UI PDUs that have the P-bit set to 0 are not acknowledged nor retransmitted.

5.3.7.1.5.2 Receiving UI command PDUs. Reception of the UI command PDU with P-bit set to 0 shall not be acknowledged. A station shall acknowledge the receipt of a valid UI command PDU, which has the P-bit set to 1 and contains the station individual address, by sending a URR response PDU to the originator of the command UI PDU. If the receiving station is unable to accept UI PDUs due to a busy condition, it shall respond with a URNR response PDU.

5.3.7.1.5.3 Sending URR response PDUs. A URR response PDU, with the F-bit set to 1, shall be sent only upon receipt of a UI command PDU, with the P-bit set to 1. The URR response PDU shall be sent to the originator of the associated UI command PDU.

5.3.7.1.5.4 Sending URNR response PDUs. A URNR response PDU, with the F-bit set to 1, may be sent by the remote station to advise the originator of the associated UI command PDU that it is experiencing a busy condition and is unable to accept UI PDUs.

5.3.7.1.5.5 Receiving UI acknowledgment. After sending a UI command PDU with the P-bit set to 1, the sending station shall expect to receive an acknowledgment in the form of a URR response PDU from the station to which the command PDU was sent. No acknowledgment shall be expected from group or global addresses or from the special address 3. Upon receiving such a response PDU, the station shall stop the acknowledgment timer associated with the transmission for which the acknowledgment was received and reset the associated internal transmission count to zero. If the response was a URNR response PDU, the sending station will stop sending UI, I, and DIA PDUs to that remote station until a URR command PDU is received or the busy-state timer expires, indicating termination of the busy condition. If High Reliability was requested for the command PDU, a DL-Status.Indication should be sent to the upper layer indicating acknowledgment success.

5.3.7.1.5.6 Sending URNR command PDUs. A URNR command PDU, with the P-bit set to 0, may be sent at any time to indicate a busy condition.

5.3.7.1.5.7 Receiving URNR command PDUs. Receipt of the URNR indicates that the sending station is busy and, with one exception described below, no additional I, UI or DIA PDUs should be sent until the sending station regains its ability to receive messages. The URNR command PDU does not contain any acknowledgment information.

**Exception:** A Station may include a busy destination in a PDU that is addressed to multiple destination addresses if at least one of the multiple destinations is not busy.

5.3.7.1.5.8 Sending URR command PDUs. A URR command PDU, with the P-bit set to 0, may be sent by a station at any time to indicate the regaining of its ability to receive messages.

5.3.7.1.5.9 Receiving URR command PDUs. The receipt of the URR command PDU cancels the prior receipt of a URNR and indicates that the sending station is now operational.

5.3.7.1.5.10 Using TEST command and response PDUs. The TEST function provides a facility to conduct loop-back tests of the station-to-station transmission path. The TEST function may be initiated within the data-link layer by any authorized station within the data-link layer. Successful completion of a test started by sending a TEST command PDU with the P-bit set consists of receiving a TEST response PDU with the F-bit set and containing no data from each individual addressee. Successful completion of a test started by sending a TEST command PDU without the P-bit set consists of receiving a TEST response PDU without the F-bit set and containing the identical data from each individual, group or global addressee. The length of the information field is variable from 0 to 128 octets. Any TEST command PDU received in error shall be discarded and no response PDU sent. In the event of a test failure, it shall be the responsibility of the TEST function initiator to determine any future actions.

5.3.7.2 Description of type 2 procedures. The procedures associated with Type 2 operation are described in 5.3.7.2.1 through 5.3.7.2.8.

5.3.7.2.1 Modes. Two modes of operation are defined for Type 2 operation: an operational mode and a non-operational mode.

5.3.7.2.1.1 Operational mode. The operational mode shall be the ABM. ABM is a balanced operational mode in which a data-link connection has been established between two stations. Either station shall be able to send commands at any time and initiate response transmissions without receiving explicit permission from the other station. Such an asynchronous transmission shall contain one or more PDUs that shall be used for information transfer and to indicate status changes in the station (for example, the number of the next expected I PDU; transition from a ready to a busy condition, or vice versa; occurrence of an exception condition). A station in ABM receiving a DISC command PDU shall respond with the UA response PDU if it is capable of executing the command. ABM consists of a data-link connection phase, an information transfer phase, a data-link resetting phase, and a data-link disconnection phase.

5.3.7.2.1.2 Non-operational mode. The non-operational mode shall be the ADM. ADM differs from ABM in that the data-link connection is logically disconnected from the physical medium such that no information (user data) shall be sent or accepted. ADM is defined to prevent a data-link connection from appearing on the physical medium in a fully operational mode during unusual situations or exception conditions. Such operation could cause a sequence number mismatch between stations or a station's uncertainty of the status of the other station. A data-link connection shall be system-predefined as to the conditions that cause it to assume ADM. Below are three examples of possible conditions, in addition to receiving a DISC command PDU, that may cause a data-link connection to enter ADM:

a. the power is turned on,

b. the data-link layer logic is manually reset, or

c. the data-link connection is manually switched from a local (home) condition to the connected-on-the-data-link (on-line) condition.

A station on a data-link connection in ADM shall be required to monitor transmissions received from its physical layer to accept and respond to one of the mode-setting command PDUs (SABME, DISC), or to send a DM response PDU at a medium access opportunity, when required. In addition, since the station has the ability to send command PDUs at any time, the station may send an appropriate mode-setting command PDU. A station in ADM receiving a DISC command PDU or any I or S PDU shall respond with the DM response PDU. A station in ADM shall not establish a FRMR exception condition. ADM consists of a data-link disconnected phase.

5.3.7.2.2 Procedure for addressing. The address fields for a PDU shall be used to indicate the individual source and up to 16 destinations. The first bit in the source address field shall be used to identify whether a command or response is contained in the PDU. A single data-link connection can be established between any two stations on the network.

5.3.7.2.3 Procedures for using the P/F bit. An individually addressed station receiving a command PDU (SABME, DISC, RR, RNR, REJ, or I) with the P-bit set to 1 shall send a response PDU with the F-bit set to 1. The response PDU returned by a station to a RSET, SABME or DISC command PDU with the P-bit set to 1 shall be a UA or DM response PDU with the F-bit set to 1. The response PDU returned by a station to an I, RR, or REJ command PDU with the P-bit set to 1 shall be an I, RR, REJ, RNR, DM, or FRMR response PDU with the F-bit set to 1. The response PDU returned by a station to an RNR command PDU with the P-bit set to 1 shall be an RR, REJ, RNR, DM, or FRMR response PDU with the F-bit set to 1. The response PDU returned by a station to a SREJ with the P-bit set to one shall be the requested I-Frame (response) with the F-bit set to one.

**NOTE:** The P-bit is usable by the station in conjunction with the timer recovery condition. (See 5.3.7.2.5.11)

5.3.7.2.4 Procedures for data-link set-up and disconnection.

5.3.7.2.4.1 Data-link connection phase. Either station shall be able to take the initiative to initialize the data-link connection.

5.3.7.2.4.1.1 Initiator action. When the station wishes to initialize the link, it shall send the SABME command PDU to one or more individual addresses and start the acknowledgment timer(s). Upon receipt of the UA response PDU, the station shall reset both the V(S) and V(R) to 0 for the corresponding data-link connection, shall stop the acknowledgment timer and shall enter the information transfer phase. When receiving the DM response PDU, the station that originated the SABME command PDU shall stop the acknowledgment timers for that link, shall not enter the information transfer phase for that station, and shall report to the higher layer for appropriate action. Should any acknowledgment timer run out before receiving all UA or DM response PDUs, the station shall resend the SABME command PDU, after deleting the address and control fields corresponding to the received UAs or DMs, and restart the acknowledgment timers. After resending the SABME command PDU N2 times, the station shall stop sending the SABME command PDU, may report to the higher layer protocol and may initiate other error recovery action. The value of N2 is defined in 5.3.8.1.2.d. Other Type 2 PDUs received (commands and responses) while attempting to connect shall be ignored by the station.

5.3.7.2.4.1.2 Respondent action. When a SABME command PDU is received, and the connection is desired, the station shall return a UA response PDU to the remote station, set both the V(S) and V(R) to 0 for the corresponding data-link connection, and enter the information transfer phase. The return of the UA response PDU shall take precedence over any other response PDU that may be pending at the station for that data-link connection. It shall be possible to follow the UA response PDU with additional PDUs, if pending. If the connection is not desired, the station shall return a DM response PDU to the remote station and remain in the link disconnected mode. For a description of the actions to be followed upon receipt of a SABME or DISC command PDU, see 5.3.7.2.4.4.

5.3.7.2.4.2 Information transfer phase. After having sent the UA response PDU to an SABME command PDU or having received the UA response PDU to a sent SABME command PDU, the station shall accept and send I and S PDUs according to the procedures described in 5.3.7.2.5. Any time a station has established a connection and enters the information transfer phase, it should also send a DL-Status Indication to its local upper layer indicating a Type 2 connection has been established. When receiving an SABME command PDU while in the information transfer phase, the station shall conform to the resetting procedure described in 5.3.7.2.6. When receiving an RSET command PDU while in the information transfer phase, the station shall conform to the resetting procedure described in 5.3.7.2.7.

5.3.7.2.4.3 Data-link disconnection phase. During the information transfer phase, either station shall be able to initiate disconnecting of the data-link connection by sending a DISC command PDU and starting the acknowledgment timer (see 5.3.8.1.2.a). When receiving a DISC command PDU, the station shall return a UA response PDU and enter the data-link disconnected phase. The return of the UA response PDU shall take precedence over any other response PDU that may be pending at the station for that data-link connection. Upon receipt of the UA or DM response PDU from a remote station, the station shall stop its acknowledgment timer for that link, and enter the link disconnected mode. Should the acknowledgment timer run out before receiving the UA or DM response PDU for a particular link, the station shall send another DISC command PDU and restart the acknowledgment timer. After sending the DISC command PDU N2 times, the sending station shall stop sending the DISC command PDU, shall enter the data-link disconnected phase, and shall report to the higher layer for the appropriate error recovery action. The value of N2 is defined in 5.3.8.1.2.d.

5.3.7.2.4.4 Data-link disconnected phase. After having received a DISC command PDU from the remote station and returned a UA response PDU, or having received the UA response PDU to a sent DISC command PDU, the station shall enter the data-link disconnected phase. In the disconnected phase, the station shall react to the receipt of an SABME command PDU, as described in 5.3.7.2.4.1, and shall send a DM response PDU in answer to a received DISC command PDU. When receiving any other Type 2 command, I or S PDU, the station in the disconnected phase shall send a DM response PDU. In the disconnected phase, the station shall be able to initiate a data-link connection. Any time a station enters the disconnected phase, it should send a DL-Status Indication to its local upper layer indicating a Type 2 connection has been disconnected.

5.3.7.2.4.5 Contention of unnumbered mode-setting command PDUs. A contention situation on a data-link connection shall be resolved in the following way: If the sent and received mode-setting command PDUs are the same, each station shall send the UA response PDU at the earliest opportunity. Each station shall enter the indicated phase either after receiving the UA response PDU, or after its acknowledgment timer expires. If the sent and received mode-setting command PDUs are different, each station shall enter the data-link disconnected phase and shall issue a DM response PDU at the earliest opportunity.

5.3.7.2.5 Procedures for information transfer. The procedures that apply to the transfer of I PDUs in each direction on a data-link connection during the information transfer phase are described in 5.3 7.2.5.1 through 5.3.7.2.5.11. When used, the term number one higher is in reference to a continuously repeated sequence series, that is, 127 is 1 higher than 126, and 0 is 1 higher than 127 for the modulo-128 series.

5.3.7.2.5.1 Sending I PDUs. When the station has an I PDU to send (that is, an I PDU not already sent), it shall send the I PDU with an N(S) equal to its current V(S) and an N(R) equal to its current V(R) for that data-link connection. At the end of sending the I PDU, the station shall increment its V(S) by 1. If the acknowledgment timer is not running at the time that an I PDU is sent, the acknowledgment timer shall be started. If the data-link connection V(S) is equal to the last value of N(R) received plus k (where k is the maximum number of outstanding I PDUs; see 5.3.8.1.2.e), the station shall not send any new I PDUs on that data-link connection, but shall be able to resend an I PDU as described in 5.3.7.2.5.6 or 5.3.7.2.5.9. Upon sending an I PDU that causes the number of outstanding I PDUs to be equal to the k2 value for that connection, the station shall send an RR (or RNR) command to the destination station. The destination station shall respond with a RR Response with the N(R) indicating the last received I PDU. When a local station on a data-link connection is in the busy condition, the station shall still be able to send I PDUs, provided that the remote station on this data-link connection is not also busy. When the station is in the FRMR exception condition for a particular data-link connection, it shall stop transmitting I PDUs on that data-link connection. When a station is in the timer recovery condition, it shall not send any new I PDUs on that data-link connection as per 5.3.7.2.5.11.

5.3.7.2.5.2 Receiving an I PDU. When the station is not in a busy condition and receives an I PDU whose N(S) is equal to its V(R), the station shall accept the information field of this PDU, increment by 1 its V(R), and act as follows:

a) If an I PDU is available to be sent, the station shall be able to act as in 5.3.7.2.5.1 and acknowledge the received I PDU by setting N(R) in the control field of the next sent I PDU to the value of its V(R). The station shall also be able to acknowledge the received I PDU by sending an RR PDU with the N(R) equal to the value of its V(R).

b) If no I PDU is available to be sent by the station, then the station shall either:

(1) If the received I PDU is a command PDU with the P-bit set to 1, then send an S PDU with its F-bit set to 1 and its N (R) equal to the current value of V (R) at the first possible opportunity (this transmission is time critical to maintaining the connection), and stop the Response Delay Timer; or

(2) If the received I PDU is not a command PDU with the P-bit set to 1, then the station shall:

(a) if the number of outstanding I PDUs received since the last I PDU for which an acknowledgment was sent is equal to or greater than *k3*, then send an S PDU with its N(R) equal to the current value of V(R) at the earliest opportunity, and stop the Response Delay Timer; else

(b) if the number of outstanding I PDUs received since the last I PDU for which an acknowledgment was sent is less than *k3*, and if the Response Delay Timer is not already running, then start the Response Delay Timer. When the Response Delay Timer is running then the station shall:

(i) if an I PDU is sent back to the originator of the recently received I PDU before the Response Delay Timer expires, then stop the Response Delay Timer. The N(R) in the outgoing I frame will acknowledge any recently received correct in sequence I PDU frames as described in 5.3.7.2.5.1 (No S PDU needs to be sent); else

(ii) if another PDU of any type that can be concatenated is transmitted to any destination and adequate space exists to concatenate additional frames, then concatenate onto this PDU an S PDU with its N(R) equal to the current value of V(R) addressed to the originator of the recently received I PDU, and stop the Response Delay Timer; else

(iii) if the Response Delay Timer expires, then at the earliest opportunity, send an S PDU with its N(R) equal to the current value of V(R). (Note that S PDUs to other destinations may be concatenated with this frame as described in the preceding paragraph.)

c) If receipt of the I PDU caused the station to go into the busy condition with regard to any subsequent I PDUs, the station shall send an RNR PDU with the N(R) equal to the value of its V(R). If I PDUs are available to send, the station shall be able to send them (as in 5.3.7.2.5.1) prior to or following the sending of the RNR PDU.

When the station is in a busy condition, the station shall be able to ignore the information field contained in any received I PDU on that data-link connection. (See 5.3.7.2.5.10.)

5.3.7.2.5.3 Receiving incorrect PDUs. When the station receives an invalid PDU or a PDU with an incorrect source address, the entire PDU shall be discarded. If an incorrect destination address is received, disregard that address field and continue processing the PDU.

5.3.7.2.5.4 Receiving out-of-sequence PDUs. When the station receives one or more I PDUs whose N(S)s are not in the expected sequence, that is, not equal to the current V(R) but is within the receive window, the station shall respond by sending a REJ or a SREJ PDU as described in either 5.3.7.2.5.4.1 or 5.3.7.2.5.4.2. Use of the SREJ is the preferred method of indicating missing frames since it allows the receiving station to request the retransmission of only those frames that are actually missing. Use of REJ to indicate missing frames results in the unnecessary retransmission of frames that were received correctly since the procedure requires that frames received out of sequence be discarded until the missing frame is received. Use of REJ to indicate missing frames is intended for use by an implementation in the case that it is providing ordered delivery of I PDUs to the next layer and adequate storage is not available (on a static or dynamic basis) within the implementation to retain out-of-sequence frames until the missing frames are received.

5.3.7.2.5.4.1 Reject response. When an I PDU has been received out-of-sequence and more than one frame is missing, the station may discard the information field of the I PDU and send a REJ PDU with the N(R) set to the value of V(R). The station shall then discard the information field of all I PDUs until the expected I PDU is correctly received. When receiving the expected I PDU, the station shall acknowledge the PDU, as described in 5.3.7.2.5.2. The station shall use the N(R) and P-bit indications in the discarded I PDU. On a given data-link connection, only one "sent REJ" exception condition from a given station to another given station shall be established at a time. A REJ and SREJ exception condition cannot be active at the same time. A "sent REJ" condition shall be cleared when the requested I PDU is received. The "sent REJ" condition shall be able to be reset when a reject timer time-out function runs out. When the station perceives by reject timer time-out that the requested I PDU will not be received, because either the requested I PDU or the REJ PDU was in error or lost, the station shall be able to resend the REJ PDU up to N2 times to reestablish the "sent REJ" condition. The value of N2 is defined in 5.3.8.1.2.d.

5.3.7.2.5.4.2 Selective reject response. When an I PDU has been received and at least one frame is missing, the station may retain the information field of the out-of-sequence I PDUs and send SREJ PDUs for the missing I PDUs. A station may transmit one or more SREJ PDUs, each containing a different N(R) with the P-bit set to 0. However, a SREJ PDU shall not be transmitted if an earlier REJ condition has not been cleared. When the station perceives by the reject timer time-out that the requested I PDU will not be received, because either the requested I PDU or the SREJ PDU was in error or lost, the station shall be able to resend all outstanding SREJ PDUs in order to reestablish the "sent SREJ" condition up to N2 times.

5.3.7.2.5.5 Receiving acknowledgment. When correctly receiving an I or S PDU, even in the busy condition (see 5.3.7.2.5.10), the receiving station shall consider the N(R) contained in this PDU as an acknowledgment for all the I PDUs it has sent on this data-link connection with an N(S) up to and including the received N(R) minus one. The station shall reset the acknowledgment timer when it correctly receives an I or Type 2 S PDU with the N(R) higher than the last received N(R) (actually acknowledging some I PDUs). If High Reliability was requested for any of the acknowledged PDU(s), a DL-Status.Indication should be sent to the upper layer indicating acknowledgment success for those PDUs. If the timer has been reset and there are outstanding I PDUs still unacknowledged on this data-link connection, the station shall restart the acknowledgment timer. If the timer then runs out, the station shall follow the procedures in 5.3.7.2.5.11 with respect to the unacknowledged I PDUs.

5.3.7.2.5.6 Receiving an SREJ PDU. If the received transmission is an SREJ command or response PDU, the I PDU corresponding to the N(R) being rejected shall be retransmitted.

5.3.7.2.5.7 Receiving an RSET PDU. Upon receipt of the RSET command PDU, the receiving station shall reply with a UA response PDU and shall then set its V(R) to 0 for the initiating station.

5.3.7.2.5.8 Receiving an REJ PDU. When receiving an REJ PDU, the station shall set its V(S) to the N(R) received in the REJ PDU control field. The station shall resend the corresponding I PDU as soon as it is available. If other unacknowledged I PDUs had already been sent on that data-link connection following the one indicated in the REJ PDU, then those I PDUs shall be resent by the station following the resending of the requested I PDU. If retransmission beginning with a particular PDU occurs while waiting acknowledgment (see 5.3.7.2.5.11) and an REJ PDU is received, which would also start retransmission with the same I PDU [as identified by the N(R) in the REJ PDU], the retransmission resulting from the REJ PDU shall be inhibited.

5.3.7.2.5.9 Receiving an RNR PDU. A station receiving an RNR PDU shall, with one exception described below, stop sending I PDUs on the indicated data-link connection at the earliest possible time and shall start the busy-state timer, if not already running. When the busy-state timer runs out, the station shall follow the procedure described in 5.3.7.2.5.11. In any case, the station shall not send any other I PDUs on that data-link connection before receiving an RR or REJ PDU, or before receiving an I response PDU with the F-bit set to 1, or before the completion of a resetting procedure on that data-link connection.

**Exception:** A Station may include a busy destination in a PDU that is addressed to multiple destination addresses if at least one of the multiple destinations is not busy.

5.3.7.2.5.10 Station-busy condition. A station shall enter the busy condition on a data-link connection when it is temporarily unable to receive or continue to receive I PDUs due to internal constraints; for example, receive buffering limitations. When the station enters the busy condition, it shall send an RNR PDU at the first possible opportunity. It shall be possible to send I PDUs waiting to be sent on that data-link connection prior to or following the sending of the RNR PDU. The station may send a URNR command PDU to the global address after the RNR PDU. While in the busy condition, the station shall accept and process supervisory PDUs and return an RNR response PDU with the F-bit set to 1 if it receives an S or I command PDU with the P-bit set to 1 on the affected data-link connection. To indicate the clearance of a busy condition on a data-link connection, the station shall send an I response PDU with the F-bit set to 1 if a P-bit set to 1 is outstanding, an REJ response PDU, or an RR response PDU on the data-link connection with N(R) set to the current V(R), depending on whether or not the station discarded information fields of correctly received I PDUs. The station may then send a URR command PDU to the global address. Additionally, the sending of a SABME command PDU or a UA response PDU shall indicate the clearance of a busy condition at the sending station on a data-link connection.

5.3.7.2.5.11 Waiting acknowledgment. The station maintains an internal retransmission count variable for each data-link connection, which shall be set to 0 when the station receives or sends a UA response PDU to a SABME command PDU, when the station receives an RNR PDU, or when the station correctly receives an I or S PDU with the N(R) higher than the last received N(R) (actually acknowledging some outstanding I PDUs). If the acknowledgment timer, busy-state timer, or the P-bit timer runs out, the station on this data-link connection shall enter the timer recovery condition and add 1 to its retransmission count variable. When a station is in the timer recovery condition, the station shall not send any new I PDUs to the destination station. The station shall then start the P-bit timer and send an S command PDU with the P-bit set to 1. The timer recovery condition shall be cleared on the data-link connection when the station receives a valid I or S PDU from the remote station with the F-bit set to 1. If, while in the timer recovery condition, the station correctly receives a valid I or S PDU with:

a. the F-bit set to 1 and the N(R) within the range from the last value of N(R) received to the current V(S) inclusive, the station shall clear the timer recovery condition, set its V(S) to the received N(R), stop the P-bit timer, and resend any unacknowledged PDUs; or

b. the P/F bit set to 0 and the N(R) within the range from the last value of N(R) received to the current V(S) inclusive, the station shall not clear the timer recovery condition but shall treat the N(R) value received as an acknowledgment for the indicated previously transmitted I PDUs. (See 5.3.7.2.5.5.)

If the P-bit timer runs out in the timer recovery condition, the station shall add 1 to its retransmission count variable. If the retransmission count variable is less than N2, the station shall resend an S PDU with the P-bit set to 1 and restart its P-bit timer. If the retransmission count variable is equal to N2, the station shall initiate a resetting procedure, by sending a SABME command PDU, as described in 5.3.7.2.6. N2 is a system parameter defined in 5.3.8.1.2.d.

5.3.7.2.6 Procedures for mode resetting. The resetting phase is used to initialize both directions of information transfer according to the procedure described in 5.3.7.2.6.1 through 5.3.7.2.6.3. The resetting phase shall apply only during ABM. Either station shall be able to initiate a resetting of both directions by sending a SABME command PDU and starting its acknowledgment timer. Any time a station resets its connection with a remote station, it should also send a DL-Status Indication to its local upper layer indicating a Type 2 connection has been reset.

5.3.7.2.6.1 Receiver action. After receiving a SABME command PDU, the station shall return one of two types of responses, at the earliest opportunity:

a. a UA response PDU and reset its V(S) and V(R) to 0 to reset the data-link connection, or

b. a DM response PDU if the data-link connection is to be terminated.

The return of the UA or DM response PDU shall take precedence over any other response PDU for that data-link connection that may be pending at the station. It shall be possible to follow the UA PDU with additional PDUs, if pending.

5.3.7.2.6.2 Initiator action. If the UA PDU is received correctly by the initiating station, it shall reset its V(S) and V(R) to 0 and stop its acknowledgment timer. This shall also clear all exception conditions that might be present at either of the stations involved in the reset. The exchange shall also indicate clearance of any busy condition that may have been present at either station involved in the reset. If a DM response PDU is received, the station shall enter the data-link disconnected phase, shall stop its acknowledgment timer, and shall report to the higher layer for appropriate action. If the acknowledgment timer runs out before a UA or DM response PDU is received, the SABME command PDU shall be resent and the acknowledgment timer shall be started. After the timer runs out N2 times, the sending station shall stop sending the SABME command PDU, and shall enter the ADM, may report to the higher layer protocol and may initiate other error recovery actions. The value of N2 is defined in 5.3.8.1.2.d. Other Type 2 PDUs, with the exception of the SABME and DISC command PDUs, received by the station before completion of the reset procedure shall be discarded.

5.3.7.2.6.3 Resetting with the FRMR PDU. Under certain FRMR exception conditions (listed in 5.3.7.2.8), it shall be possible for the initiating station, by sending an FRMR response PDU, to ask the remote station to reset the data-link connection. Upon receiving the FRMR response PDU (even during a FRMR exception condition), the remote station shall either initiate a resetting procedure, by sending a SABME or RSET command PDU, or initiate a disconnect procedure, by sending a DISC command PDU. After sending an FRMR response PDU, the initiating station shall enter the FRMR exception condition. The FRMR exception condition shall be cleared when the station receives or sends a SABME or DISC command PDU, DM response PDU or RSET command PDU. Any other Type 2 command PDU received while in the FRMR exception condition shall cause the station to resend the FRMR response PDU with the same information field as originally sent. In the FRMR exception condition, additional I PDUs shall not be sent, and received I and S PDUs shall be discarded by the station. It shall be possible for the station to start its acknowledgment timer on the sending of the FRMR response PDU. If the timer runs out before the reception of a SABME or DISC command PDU from the remote station, it shall be possible for the station to resend the FRMR response PDU and restart its acknowledgment timer. After the acknowledgment timer has run out N2 times, the station shall reset the data-link connection by sending a SABME command PDU. The value of N2 is defined in 5.3.8.1.2.d. When an additional FRMR response PDU is sent while the acknowledgment timer is running, the timer shall not be reset or restarted.

5.3.7.2.7 Procedures for sequence number resetting. This resetting procedure, employing the RSET command, is used to reinitialize the receive-state variable V(R) in the addressed station and the send-state variable V(S) in the local station. The addressed station shall confirm acceptance of the RSET command by transmission of a UA response at the earliest opportunity. Upon acceptance of this command, the addressed station V(R) shall be set to 0. If the UA response is received correctly, the initializing station shall reset its V(S) to 0. The RSET command shall reset all PDU rejection conditions in the addressed station, except for an invalid N(R) sequence number condition which the addressed station has reported by a FRMR. The RSET command may be sent by the station that detects an invalid N(R) to clear such a frame rejection condition in place of sending a FRMR frame. To clear an invalid N(R) frame rejection condition with an RSET command, the RSET command shall be transmitted by the station that detects the invalid N(R). A station may resend the contents of the information field of unacknowledged outstanding I PDUs. Any time a station resets its connection with a remote station, it should also send a DL-Status Indication to its local upper layer indicating a Type 2 connection has been reset.

5.3.7.2.8 FRMR exception conditions. The station shall request a resetting procedure by sending an FRMR response PDU, as described in 5.3.7.2.6.3, after receiving, during the information transfer phase, a PDU with one of the conditions identified in 5.3.6.2.3.6. The coding of the information field of the FRMR response PDU that is sent is given in 5.3.6.2.3.6. The other station shall initiate a resetting procedure by sending a SABME or RSET command PDU, as described in 5.3.7.2.6, after receiving the FRMR response PDU.

5.3.7.3 Description of type 4 procedures. The procedures associated with Type 4 operation are described in 5.3.7.3.1 through 5.3.7.3.5.3.

5.3.7.3.1 Modes of operation. In Type 4 operation, no modes of operation are defined. A station using Type 4 procedures shall support the entire set whenever it is operational on the network.

5.3.7.3.2 Procedures for addressing. The address field shall be used to indicate the source and destinations of the transmitted PDU. The first bit in the source address shall be used to identify whether a command or a response is contained in the PDU. Individual, group, and global addressing shall be supported for the destination addresses in command PDUs. The source address shall contain an individual address.

5.3.7.3.3 Procedure for using the P/F bit. The P/F bit is not implemented in Type 4 operation.

5.3.7.3.4 Procedures for logical data-link set-up and disconnection. Type 4 operation does not require any prior data-link set-up and disconnection. Data-link set-up and disconnection procedures are not required for Type 4 operation. All stations shall advance to the information transfer state.

5.3.7.3.5 Procedures for information transfer.

5.3.7.3.5.1 Sending DIA command frames. The DIA PDU may either be a new PDU from the local user, or a retransmission of a DIA PDU which was not acknowledged within the period determined by the T1 parameter. DIA PDUs are retransmitted up to N2 times, where N2 is as specified by the station parameters. If a DIA PDU is not acknowledged after N2 retransmissions, a DL-Status-Indication should be sent to the upper layer indicating an acknowledgment failure.

5.3.7.3.5.2 Receive not ready procedure.

5.3.7.3.5.2.1 Sending a DRNR command PDU. A station may generate and transmit a DRNR command PDU if its Quiet Mode is disabled and it receives a DIA PDU which it cannot accept because its receive buffers are full. A station may generate a DRNR command PDU when directed by the management function (e.g., operator). The DRNR command S PDU does not acknowledge a DIA PDU. The station may send a URNR command PDU to the global address after the DRNR PDU.

5.3.7.3.5.2.2 Receiving a DRNR command PDU. Upon receipt of a DRNR PDU a station shall, with one exception described below, inhibit transmission of DIA PDUs to the station which originated the DRNR command by updating the station status table to reflect this busy condition. The DRNR PDU shall not change the Quiet Mode status of a station. Any PDUs in the Retransmission queue addressed to the busy station shall be modified to delete (null) the busy station from the destination address list. Normal transmissions of DIA PDUs to that station shall resume upon receipt of a DRR command from the station.

**Exception:** A Station may include a busy destination in a PDU that is addressed to multiple destination addresses if at least one of the multiple destinations is not busy.

5.3.7.3.5.2.3 Sending a DRNR response PDU. A station shall generate and transmit a DRNR response PDU after it has sent a DRNR command PDU (if its Quiet Mode is disabled) while it is processing frames in its receive queues in the busy condition. A DRNR response acknowledges the DIA PDU indicated in the PDU identification number field while reinforcing the station's busy condition.

5.3.7.3.5.2.4 Receiving a DRNR response PDU. Upon receipt of a DRNR response PDU, a station shall search the destination addresses associated with the identification number in the DRNR response PDU. The response PDU originator's address shall be deleted from the destination address field (if it is still there) of the DIA being acknowledged.

5.3.7.3.5.3 Receive ready procedures.

5.3.7.3.5.3.1 Sending a DRR PDU. A station shall generate and transmit a DRR PDU if its Quiet Mode is disabled and one of the following conditions exist.

a. The station is no longer busy and had previously sent a DRNR command PDU.

b. The station is not busy and the station received a DIA PDU from a transmitting station which requires acknowledgment.

c. If directed by the user interface.

5.3.7.3.5.3.1.1 Sending a DRR command PDU. The DRR command PDU is generated and transmitted by a station to indicate the end of a Type 4 busy/buffer full condition. The DRR command S PDU does not acknowledge DIA PDUs. The DRR command PDU only changes the busy status to DRR. This frame does not change the Quiet Mode status. The station may send a URR command PDU to the global address after the DRR PDU.

5.3.7.3.5.3.1.2 Sending a DRR response PDU. The DRR response PDU is generated and transmitted by a station whose Quiet Mode is disabled to acknowledge the acceptance of a DIA PDU, and is addressed to the originator of the DIA PDU. The DIA PDU which is being acknowledged is indicated by the PDU identification number.

5.3.7.3.5.3.2 Receiving a DRR response PDU. Upon receipt of a DRR response PDU a station shall search the destination addresses associated with the identification number in the DRR response PDU. The DRR response PDU originator's address shall be deleted from the destination address field of the DIA being acknowledged. If High Reliability was requested for the DIA, a DL-Status Indication should be sent to the upper layer indicating acknowledgment success.

5.3.8 Data-link initialization. The XNP messages, described in Appendix E, are used to establish and control link parameters. The Join Request message contains the link operating parameters such as net busy detect time, subscriber rank, and net access method. Initialization is caused by an operator or system request. The Join Request is sent to the default network control (NETCON) destination address, which shall be the station assigned to perform NETCON station responsibilities. The NETCON station verifies link parameters and provides values for missing or incorrect parameters to ensure that the new station will not disrupt the net. The NETCON station will reply with either a Join Reject or Join Accept PDU. If the initializing station receives a Join Reject PDU, it should not attempt any link activity until the correct parameters have been obtained.

**NOTE:** Link initialization may also occur without an XNP message exchange. Prearrangement by timing, voice, written plans, or orders provides the operator with the necessary frequency, link address, data rate, and other parameters to enter a net and establish a link. With the prearranged information, an operator may begin link activity on the net and initialization is assumed when the new station senses the net and transmits its first message.

5.3.8.1 List of data-link parameters. This document defines a number of data-link parameters for which the system-by-system range of values are determined at network establishment. The maximum number of octets in the information field of a UI, I or DIA PDU is an adjustable data-link parameter in the range of 708 - 3345. The definitions of additional parameters for the three types of operation are summarized in 5.3.8.1.1 through 5.3.8.1.3.

5.3.8.1.1 Type 1 logical data-link parameters. The logical data-link parameters for Type 1 operation shall be as follows:

a. Acknowledgment timer. The acknowledgment timer is a data-link parameter that shall define the timeout period (TP) during which the sending station shall expect an acknowledgment from a specific destination station. The acknowledgment timer should not be activated until the corresponding PDU has been transmitted. TP shall take into account any delay introduced by the physical sublayer. The value of TP is described in Appendix C (C4.3).

b. Busy-state timer. The busy-state timer is a data-link parameter that defines the time interval following receipt of the URNR command PDU during which the station shall wait for the other station to clear the busy condition. Default value is 120 seconds.

c. Maximum number of retransmissions, N4. N4 is a data-link parameter that indicates the maximum number of times that an UI or TEST command PDU is retransmitted by a station trying to accomplish a successful information exchange. Normally, N4 is set large enough to overcome the loss of a PDU due to link error conditions. The maximum number of times that a PDU is retransmitted following the expiration of the acknowledgment timer is established at protocol initialization. This value is in the range of 0 through 5 and defaults to 2. The retransmission of PDUs may be overridden by the Quiet Mode parameter, which is described in 5.3.11.2.

d. Minimum number of octets in a PDU. The minimum-length valid data-link PDU shall contain 2 flags, 2 addresses, one 8-bit control field, and the FCS. The minimum number of octets in a valid data-link PDU shall be 9.

5.3.8.1.2 Type 2 data-link parameters. The data-link connection parameters for Type 2 operation shall be as follows:

a. Acknowledgment timer. The acknowledgment timer is a data-link connection parameter that shall define the time interval during which the station shall expect to receive acknowledgment to one or more outstanding I PDUs or an expected response to a sent U command PDU. The acknowledgment timer should not be activated until the corresponding PDU has been transmitted. Time values are established at protocol initialization and are in the range of 10 to 1800 seconds in one-second increments. Default is 120 seconds.

b. P-bit timer. The P-bit timer is a data-link connection parameter that defines the time interval during which the station shall expect to receive a frame with the F-bit set to 1 in response to a sent Type 2 command with the P-bit set to 1. The P-bit timer should not be activated until the corresponding PDU has been transmitted. Time values are established at protocol initialization and are in the range of 10 to 60 seconds in increments of 1 second. Default is 10 seconds.

c. Reject timer. The reject (REJ) timer is a data-link connection parameter that defines the time interval during which the station shall expect to receive a reply to a sent REJ or SREJ PDU. The reject timer value shall be equal to or less than twice the acknowledgment timer. The reject timer should not be activated until the corresponding PDU has been transmitted.

d. Maximum number of retransmissions, N2. N2 is a data-link connection parameter that indicates the maximum number of times that a PDU (including the S command PDU that is sent as a result of the acknowledgment P-bit or reject timer expiring) is sent, following the running out of the acknowledgment timer, the P-bit timer, or the reject timer. The maximum number of times that a PDU is retransmitted following the expiration of the timers is established at protocol initialization. This value is in the range of 0 through 5 and defaults to 2. The retransmission of PDUs may be overridden by the Quiet Mode parameter, which is described in 5.3.11.2.

e. Maximum number of outstanding I PDUs, *k*. The maximum number (*k*) of sequentially numbered I PDUs that the sending station may have outstanding (i.e. unacknowledged) on a single data-link connection simultaneously. The value of this parameter is in the range 1 through 127. (This value of this parameter may be established through the use of the Type 2 *k* Window field of an XNP message as described in Appendix E, "Type 2 Parameters".)

f. Maximum number of outstanding I PDUs at which an acknowledgment is requested, *k2*. The maximum number (*k2*) of outstanding (i.e. unacknowledged) I PDUs that can be sent by a source station on a data-link connection before the station requests acknowledgment. When this threshold is reached the sending station sends an S PDU that both acknowledges received I frames and causes an S PDU to be sent in return to acknowledge outstanding I PDUs. The value of this parameter is in the range 1 through 127, but would normally be less than or equal to the value of parameter *k*.

g. Maximum number of outstanding received I PDUs threshold, *k3*. The maximum number (*k3*) of correct in sequence I PDUs received on a data-link connection since the last I PDU received on the data-link connection was acknowledged. When this threshold is reached the receiving station generates a S PDU to acknowledge received frames. The value of this parameter is in the range 1 through 127, but would normally be less than or equal to the value of parameter *k*.

h. Response delay timer. The amount of time that a station waits after an I PDU Response or an I PDU Command with its P-bit set to 0 is received until it is acknowledged by transmission of a S PDU in the case that no other frames are available for transmission. The value of this parameter is in the range of 1 to 1800 seconds in one-second increments, but will normally be less that the value of the Acknowledgment Timer parameter. (The value of this parameter may be established by the Type 2 Acknowledgment Timer and Response Timer fields of an XNP Parameter Update message as described in Appendix E, "Type 2 Parameters".)

i. Minimum number of octets in a PDU. A minimal-length valid data-link connection PDU shall contain exactly 2 flags, 2 address fields, 1 control field, and the FCS. Thus, the minimum number of octets in a valid data-link connection PDU shall be 9 or 10, depending on whether the PDU is a U PDU, or an I or S PDU, respectively.

5.3.8.1.3 Type 4 data-link parameters. The logical data-link parameters for Type 4 operation shall be as follows:

a. Acknowledgment (T1) timer. The T1 timer is the maximum time a station shall wait for an acknowledgment of a transmitted DIA PDU before that PDU is retransmitted. The value of T1 shall be in the range of 5-120 seconds in increments of 0.2 seconds. Each DIA PDU transmitted shall be assigned a T1 timer. When the T1 timer expires for DIA PDU, that DIA PDU shall be retransmitted in the next transmission opportunity for that precedence, assuming the N2 count has not been reached. DIA PDUs with only one destination will be discarded if the destination replied with a DRNR or DRR response PDU. If the DIA PDU is multi-addressed, the receive station is removed (nulled) from the destination address field. This timer shall be paused whenever the net is busy with voice. This timer is resumed when voice transmission has completed.

b. Maximum number of retransmission attempts, N2. The N2 parameter shall indicate the maximum number of retransmission attempts to complete the successful transmission of a DIA PDU. The value of N2 shall be the maximum retransmit value (range = 0-5).

c. k maximum number of outstanding DIA frames. The value of *k* indicates the maximum number of DIA PDUs that a station may have outstanding (awaiting acknowledgment) to all stations at any given time. The value of *k* ranges from 5 - 20 DIA PDUs.

5.3.9 Frame transfer. After the station has joined the net, it can begin to send frames. The data-link layer shall request the transmission of a frame by issuing a Unitdata request to the physical layer.

5.3.9.1 PDU transmission. The data-link layer initiates transmission by building a transmission unit and passing it to the physical layer. The elements of a transmission unit include one transmission header (see 5.3.1), one or more PDUs (see data-link concatenation, below), the additional bits resulting from the operations of zero-bit-insertion, optional FEC encoding, optional TDC and optional scrambling. To request transmission, a PL-Unitdata-Request is issued by the data-link layer protocol after a transmission unit has been constructed. PDUs shall be queued for transmission in such a manner that the highest precedence PDUs are transmitted before lower precedence PDUs. If a prioritized net access scheme is active, the precedence access level used shall be the precedence of the PDU that is to be transmitted next. Transmission units of the same precedence shall be in first-in first-out order. Type 2 I PDUs for a particular connection shall be transmitted in the order of their sequence numbers. Any PDUs may be concatenated at the data-link layer or physical layer except Type 1 PDUs with the P bit set to 1.

5.3.9.2 Data-link concatenation. The sending station may concatenate any PDUs, except Type 1 PDUs that require the TP timer (P bit set to 1), by using one or two flags to separate each PDU. All receiving stations shall be able to de-concatenate the reception into separate PDUs. The combined length of the concatenated PDUs, before 0-bit insertion, may not exceed the established maximum PDU size for a single PDU (see 5.3.8.1). The PDUs are concatenated after the 0-bit insertion algorithm is applied. FEC, with or without TDC, and scrambling are optionally applied before the transmission unit is passed to the physical layer in a PL-Unitdata-Request. Data-link concatenation to add another interior data frame shall not be performed if the resulting frame would take longer to transmit than the maximum transmit time allowed for the network. Data-link concatenation is shown in Figure 22.

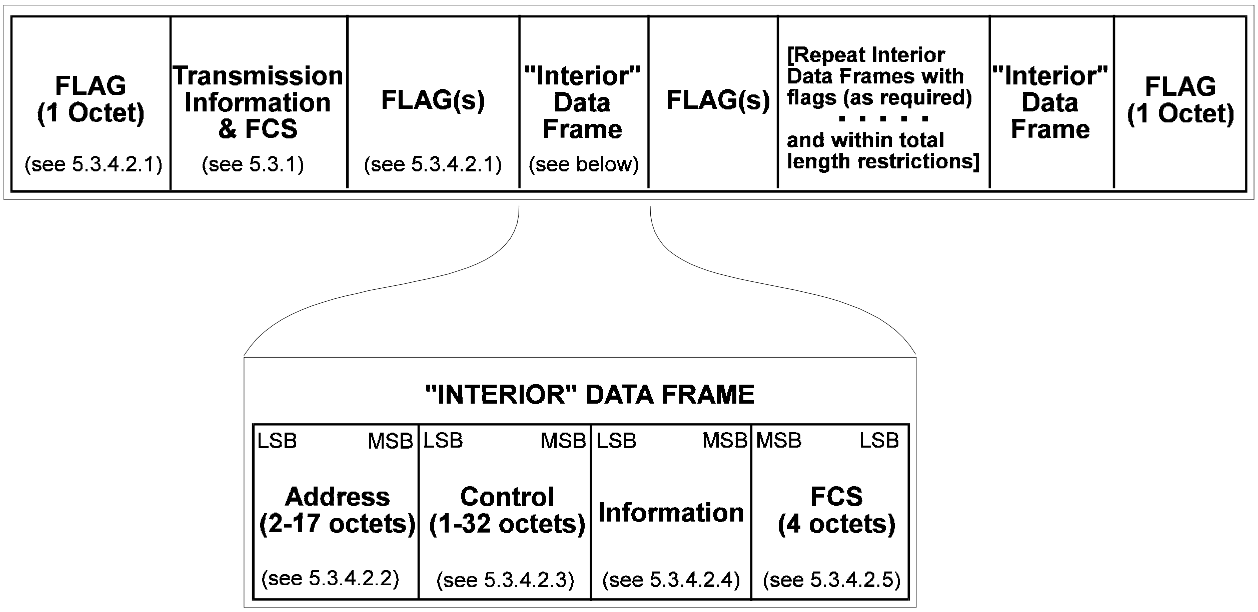



FIGURE 22. Data-link concatenation.

5.3.9.3 Physical-layer concatenation. Physical layer concatenation does not apply when Packet Mode is used. More than one PDU may be passed to the physical layer without waiting for an intervening net access delay period. The time to transmit the combined length of the transmission frame, shall not exceed the maximum transmit time allowed for the network. The physical layer shall transmit each transmission unit following the complete physical layer procedures with no additional bits between Interior Transmission Units (except for bit synchronization when used in Asynchronous Mode). Physical layer concatenation is shown in Figure 23. Note that the Phasing field described in 5.2.1.2 shall precede the first Interior Transmission Unit only.

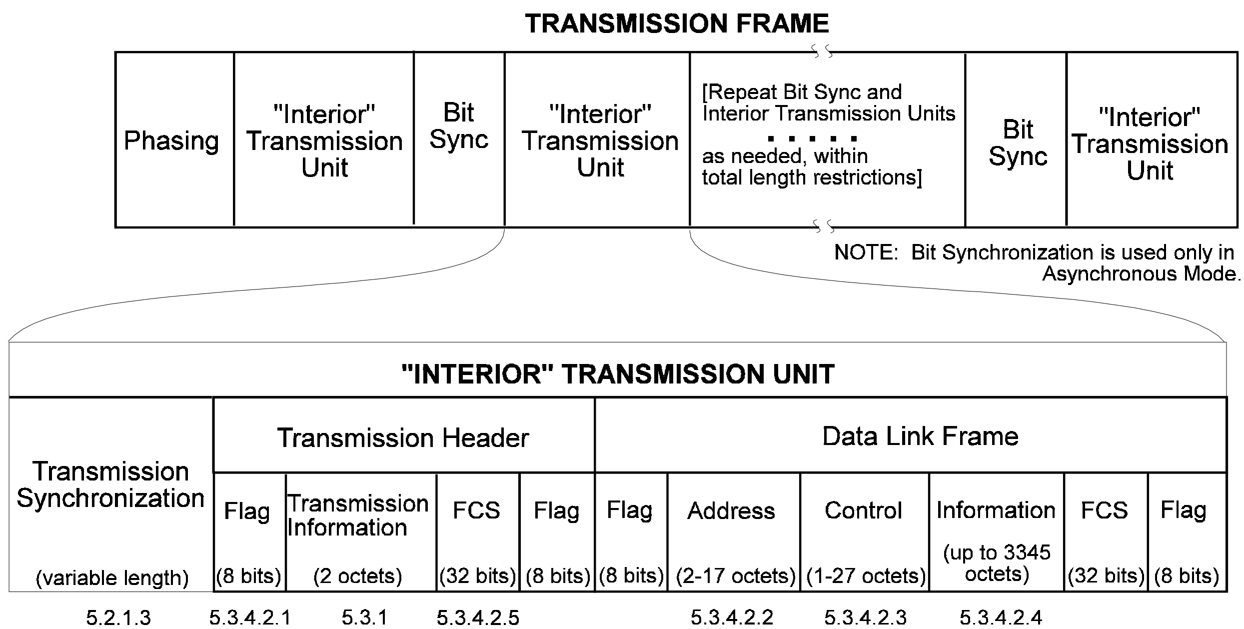



FIGURE 23. Physical-layer concatenation.

5.3.9.4 PDU transmissions. Both data link layer and physical layer concatenation may be used to build a single transmission frame. All types of operation PDUs, except Type 1 PDUs with the P-bit set may be concatenated within the same single transmission frame. PDUs are placed in the appropriate precedence-level queue, with each level queue using a single first-in first-out order. If the first PDU in the highest precedence level queue (or only queue) may be concatenated, then other PDUs may be concatenated with that PDU even if a PDU that does not allow concatenation is queued ahead of them. The PDU that did not allow concatenation shall be at the head of its appropriate queue for the next net access period. If the first PDU in the highest precedence level queue (or only queue) does not allow concatenation, it shall be the only PDU transmitted in that net access period.

5.3.10 Flow control. Flow control provides the capability of reducing the allowed input rate of information to prevent congestion to the point where normal operation may become impossible. The control-field sequence numbers are available for this service.

5.3.10.1 Type 1 flow control. Type 1 transmissions can be acknowledged or unacknowledged. Acknowledged and unacknowledged operations can perform flow control using URR and URNR messages. These messages announce the station's ability to accept incoming frames.

5.3.10.2 Type 2 flow control. The send and receive sequence numbers, N(S) and N(R), are used in conjunction with the send- and receive-state variables, V(S) and V(R), to control data flow. Flow control is implemented by the window method. The window defines the maximum number of undelivered frames a given user may have outstanding. The maximum number (*k*) of sequentially numbered I PDUs that may be outstanding (that is, unacknowledged) at any given time is a data-link connection parameter, which shall never exceed 127. The incremental updating of N(R) acts as the positive acknowledgment of transmitted frames up to, but not including, that frame number. The window flow-control mechanism requires that the highest sequence number transmitted by the user be less than the sum of the last received N(R) plus *k* mod MODULUS (see 5.3.5.2.1). Window size (*k*) is a feature that is agreed upon by the users at initialization. The larger the window, the greater the traffic loading a given user places on a single channel.

5.3.10.3 Type 4 flow control. Type 4 flow control is performed using DRR and DRNR messages. These messages indicate a station's ability to accept incoming DIA frames. In addition, a window method is used to define the maximum number of frames a given station may have outstanding. The maximum number of DIA PDUs that may be outstanding (unacknowledged) at any given time is the Type 4 *k* parameter.

5.3.11 Acknowledgment and response. All UI, DIA or I PDUs that require an acknowledgment shall be acknowledged except for the following cases:

a. the control field of the received PDU specifies that no acknowledgment is required,

b. the Quiet Mode (described in 5.3.11.2), has been set to ON,

c. the receiving station is a group (including global) addressee only,

d. the receiving station's individual address is not in the address field, or

e. the PDU is invalid.

5.3.11.1 Acknowledgment. Acknowledgments are applicable for Type 1, Type 2 and Type 4 operations.

5.3.11.1.1 Type 1 acknowledgment. Each PDU, with the P-bit set to 1, shall be responded to before another PDU is transmitted. This is defined as a coupled acknowledgment. All UI and TEST command PDUs that have the P-bit set to 1 shall be acknowledged. The RHD procedures (see C4.2) shall be followed by all stations on the network to allow each responding station an interval in which they can transmit their response.

5.3.11.1.2 Type 2 acknowledgment. Type 2 PDUs that require acknowledgment shall activate the acknowledgment timer. Type 2 also uses P and F-bit procedures for acknowledgments, but these P and F-bit procedures do not involve coupled acknowledgments. The Type 2 operation does not use the RHD timer, which allows receiving stations to send their acknowledgments during the current net access period. All acknowledgments are transmitted in another net access period. An I PDU acknowledgment does not necessarily correspond on a one-to-one basis with the I PDU and does not necessarily apply to the immediately preceding I PDU.

5.3.11.1.3 Type 4 acknowledgment. The DIA PDU shall activate the acknowledgment timer. The Type 4 operation does not use the RHD timer. All acknowledgments are sent in another channel access period. All DIA PDUs are independently acknowledged.

5.3.11.2 Quiet mode. The protocol shall allow an operator to initiate Quiet Mode as an override feature that, when invoked, prevents any transmission (including retransmission) without explicit permission from the operator. As a security feature, the operator shall be able to turn off automatic transmissions but still continue to receive. Normal protocol exchanges shall occur when the Quiet Mode is OFF. Only the operator can initiate a transmission when the Quiet Mode is ON. The Quiet Mode shall override the Maximum Number of Retransmissions data-link parameters. The default value of the Quiet Mode is OFF. If the Quiet Mode is ON during Type 2 operations, the flow control mechanism and retransmission timers in the remote system will eventually cause the connection to be lost. UI, I, or DIA PDUs received by a station with Quiet Mode ON shall be serviced in the normal way except nothing will be returned nor queued for later transmission.

5.3.11.3 Immediate retransmission. Certain time critical exchanges require immediate retransmission if the acknowledgment is not received in the allocated response interval. This is accomplished by using the special address of 3 in the destination field with the Type 1 operation with the P-bit set to 1. All receiving stations calculate their TP based upon the total number of individual and special addresses. The sending station shall not include the special address 3 in its TP calculation and shall schedule any necessary retransmissions during the longer TP experienced by other stations.

5.3.12 Invalid frame. A frame is invalid if it has one or more of the following characteristics:

a. not bounded by a beginning and ending flag,

b. too short,

c. too long,

d. has an invalid address or control field, and

e. has an FCS error.

A frame is too short if it contains less than 9 bytes. A frame is too long if it exceeds the maximum PDU length as described in 5.3.8.1. Any invalid frame shall be discarded.

5.3.13 Retransmission. The data-link layer will retransmit a command frame waiting for a response. The default number of retransmissions is 2, but the data-link layer protocol may be initialized to automatically retransmit 0 to 5 times. If the Quiet Mode is ON, no automatic retransmissions shall be made.

5.3.14 Error detection and correction. FEC coding alone, or FEC coding in unison with TDC, may be used to provide error detection and correction (EDC) capabilities to compensate for errors induced during transmission. If selected, the FEC process shall be used to encode the data-link frame of 5.3.4. If selected, the TDC process shall be applied to the FEC-encoded data-link frame and to the fill bits. Three modes of EDC shall be supported: FEC OFF, FEC ON with TDC, and FEC ON without TDC (NOTE: FEC ON without TDC may be used when the transmission channel provides the TDC capability). The EDC modes are selectable.

5.3.14.1 Forward-error-correction coding. When FEC is selected, the Golay (24,12) cyclic block code, described in detail in Appendix F, shall be used for FEC. The generator polynomial to obtain the 11 check bits shall be

$$g(x) = x^{11} + x^{10} + x^{6} + x^{5} + x^{4} + x^{2} + 1$$

where g(x) is a factor of $x^{23} + 1$.

5.3.14.2 Forward-error-correction preprocessing. When FEC is selected, data bits shall be divided into a sequence of 12-bit segments for Golay encoding. The total number of segments shall be an integral number. If the data bits do not divide into an integral number of segments, fill bits, consisting of 1 to 11 0's, shall be added at the end to form an integral number of segments. Coupled acknowledgment of Type I URR, URNR and TEST Response frames with their F-bit set shall be duplicated, including the beginning and ending flag, when FEC and TDC are selected. This provides a station with two opportunities to receive an error-free frame. The duplicated copy shall always start at the exact midpoint of the TDC Block.

5.3.14.3 Time-dispersive coding. TDC bit interleaving may be selected in unison with FEC. When TDC is selected, data shall be formatted into a sequence of TDC blocks composed of sixteen 24-bit Golay (24, 12) codewords (that is, there are 384 FEC-encoded bits per TDC block). Each TDC block shall contain a total of 16 FEC codewords. If the last TDC block of a message contains less than 16 FEC codewords, fill codewords shall be added to complete the TDC block. These 24-bit fill codewords shall be created by Golay-encoding an alternating sequence of 12-bit data words, with the first word composed of 12 ones followed by a word composed of 12 zeros. The fill codewords shall alternate until the TDC block is filled. The TDC block shall be structured into a 16 x 24 matrix (the Golay codewords appear as rows), as shown in Figure 24.

$A_1$ through $A_{24}$ are the bits of the first Golay codeword. $A_{25}$ is the first bit of the second Golay codeword. Each TDC block matrix shall be rotated to form a 24 x 16 matrix. The Golay codewords now appear as columns, as shown in Figure 25. The TDC block is transmitted row by row with the LSB ($A_1$) of the first row first. At the receiver, the TDC-encoded bit stream shall be structured into a 24 x 16 matrix. Each received TDC block matrix shall be rotated to form the original 16 x 24 matrix, as shown in Figure 24. The TDC decoder at the receiver shall perform the inverse of the TDC encoding process.

| | | | | | | |
|---|---|---|---|---|---|---|
| $A_1$ | $A_2$ | | | | $A_{23}$ | $A_{24}$ |
| $A_{25}$ | $A_{26}$ | | | | $A_{47}$ | $A_{48}$ |
| $A_{49}$ | $A_{50}$ | | | | $A_{71}$ | $A_{72}$ |
| | | | | | | |
| $A_{361}$ | $A_{362}$ | | | | $A_{383}$ | $A_{384}$ |

Golay Codeword in each row
$A_1$, $A_2$ , $A_3$, ... , $A_4$

FIGURE 24. 16 x 24 matrix before interleaving.

| | | | | | | |
|---|---|---|---|---|---|---|
| $A_1$ | $A_{25}$ | | | | $A_{337}$ | $A_{361}$ |
| $A_2$ | $A_{26}$ | | | | $A_{338}$ | $A_{362}$ |
| $A_3$ | $A_{27}$ | | | | $A_{339}$ | $A_{363}$ |
| | | | | | | |
| $A_{24}$ | $A_{48}$ | | | | $A_{360}$ | $A_{384}$ |

Golay Codeword in each row
$A_1$, $A_{25}$, .... $A_{337}$, $A_{361}$

FIGURE 25. Transmitter's 24 x 16 matrix after interleaving.

5.3.15 Data scrambling. Data scrambling must be performed if the transmission medium does not have a DC response and there is the possibility that "long" strings of NRZ ones or zeros are transmitted. Long is a relative term that is dependent on the data rate, the low frequency channel cutoff frequency, and the channel signal-to-noise ratio (S/N), since at low S/N there is less margin for DC drift.

a. At the Data Link layer, the Transmission Header selects a CCITT V.36 scrambler, which includes a randomizer function as well as a pseudo-noise (PN) generator. It is applied inside the FEC (that is, before FEC is applied).

b. CCITT V.36 scrambling shall not be applied outside the FEC because bit errors at the receiver will be extended. In addition, a CCITT V.33 scrambler, which uses a PN generator but not a randomizer, is specified for use at the physical layer. In a high bit error rate environment this extension will become catastrophic. For that reason a CCITT V.33 scrambler, which uses a PN generator but not a randomizer, is specified for use at the Physical layer (as part of the multi-dwell protocol; see

J3.3). In both cases, there is a very small probability that the interleaving for the Data Link layer scrambler or the fixed PN sequence for the Physical layer scrambler may do more harm than good. Therefore, they are individually selectable. Both scramblers should not be used at the same time. If CCITT V.36 scrambling/descrambling is used, the contents of the adverse state detector (ASD) and the 20-state shift register shall be initialized to all ones prior to scrambling or descrambling data link frames in each interior transmission unit.

5.3.16 Link layer interactions. The data-link layer interacts with both the next higher and next lower layer to pass or receive information regarding services requested or performed. Three primitives are used to pass information for the sending and receiving of data across the upper layer boundary.

a. Requests for transmission of data are sent by the upper layer, using the data-link layer (DL) Unitdata Request primitive, with the following parameters:

- DL-Unitdata Request
  - Message ID
  - Destination(s)
  - Source
  - Topology Update ID
  - Quality of Service
    - Precedence
    - Throughput Requested (Normal/High)
    - Delay Requested (Normal/Low)
    - Reliability Requested (Normal/High)
  - Data/Data Length

b. Indications are provided to the upper layer through the DL-Unitdata Indication and DL-Unitdata Status Indication primitives with the following parameters:

- DL-Unitdata Indication
  - Destination(s)
  - Source
  - Topology Update ID
  - Data/Data Length

- DL-Status Indication
  - Message ID
  - Destination(s)
  - Acknowledgment Success/Failure
  - Connection Status
  - Neighbor detection

c. Descriptions of the above parameters follow:

(1) Message ID is an indicator established by the upper layer in the DL-Unitdata Request and used to associate a subsequent DL-Status Indication acknowledgment status with that request.

(2) The destination(s) can be 1 to 16 individual, special or multicast (including global) addresses.

(3) The source address is the individual address of the outgoing link.

(4) Topology Update ID, in a DL-Unitdata Request, shall contain the most recent Topology Update ID sent from the upper layer. Topology Update ID, in a DL-Unitdata Indication, shall contain the Topology Update Identifier field from the Transmission Header.

(5) Quality of Service parameters are used to determine the service provided by the data-link layer.

(a) Precedence parameters are used by the prioritized transmission scheme and are used to order outgoing queues. The precedence levels available to the network will be mapped into three levels (urgent, priority, and routine) in the data-link layer. Precedence levels in the network layer shall be mapped as shown in Table IX.

(b) Precedence and the other Quality of Service parameters are used to select a preferred data link type of procedure. The recommended mapping shown in Table X is provided for guidance.

(6) Data/Data Length is the block of data exchanged between the data-link layer and its upper layer user, and an indication of the data's length.

(7) Acknowledgment Success/Failure is an indicator to inform the upper layer whether a data-link acknowledgment was received from the remote station when high reliability was requested in a Unitdata Request.

(8) Connection Status is an indicator to inform the upper layer if a Type 2 connection has been established, reset or disconnected.

(9) Neighbor detection is an indicator to inform the upper layer when a data-link transmission is detected from a previously unknown station.

TABLE IX. Network layer to data link layer precedence mapping.

| Network Precedence | Data-Link Precedence |
|---|---|
| Critic/ECP<br>Flash Override<br>Flash<br>Network Control (NETCON)<br>Internet Control | URGENT |
| IMMEDIATE<br>PRIORITY | PRIORITY |
| ROUTINE | ROUTINE |

TABLE X. Mapping intranet TOS field to data link type of service.

| TOS | | STATION CLASS (see 5.3.3.5) | | | |
|---|---|---|---|---|---|
| **DTR** | **Precedence** | **A** | **B** | **C** | **D** |
| 000<br>(& other) | Urgent<br>Priority<br>Routine | **1 (ACK)<br>1 (ACK)<br>1 (No ACK)** | **1 (ACK)<br>2<br>2** | **1 (ACK)<br>1 (ACK)<br>4** | **1 (ACK)<br>2<br>4** |
| 100 | Urgent<br>Priority<br>Routine | **1 (ACK)<br>1 (ACK)<br>1 (No ACK)** | **1 (ACK)<br>2<br>1 (No ACK)** | **1 (ACK)<br>1 (ACK)<br>1 (No ACK)** | **1 (ACK)<br>2<br>1 (No ACK)** |
| 010 | Urgent<br>Priority<br>Routine | **1 (ACK)<br>1 (ACK)<br>1 (No ACK)** | **2<br>2<br>2** | **1 (ACK)<br>1 (ACK)<br>4** | **2<br>2<br>2** |
| 001 | Urgent<br>Priority<br>Routine | **1 (ACK)<br>1 (ACK)<br>1 (ACK)** | **2<br>2<br>2** | **1 (ACK)<br>1 (ACK)<br>4** | **2<br>2<br>2** |

**NOTE:** Type 3 Immediate Retransmission is invoked for Urgent precedence messages when DTR is 000 or 100.

5.4 Network layer.

5.4.1. Intranet protocol. The Intranet layer, layer 3a, has been dedicated to routing intranet packets between a source and possibly multiple destinations within the same radio network. The intranet layer also accommodates the exchange of topology and connectivity information. An Estelle language formal specification of the Intranet layer is available via the CNR Implementation Working Group World Wide Web page: http://www-cnrwg.itsi.disa.mil.

5.4.1.1 Intranet header. Figure 26 defines the Intranet header. For Intranet relaying and message types 1, 2 and 3, the entire header shall be used. Otherwise, only the Version Number, Message Type, Intranet Header Length and Type of Service shall be used. The Intranet header shall only be used with UI, I and DIA PDUs.

<table>
<tr><td>LSB<br>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>MSB<br>7</td></tr>
<tr><td colspan="4">VERSION NUMBER</td><td colspan="4">MESSAGE TYPE</td></tr>
<tr><td colspan="8">INTRANET HEADER LENGTH</td></tr>
<tr><td colspan="8">TYPE OF SERVICE</td></tr>
<tr><td colspan="8">MESSAGE IDENTIFICATION NUMBER</td></tr>
<tr><td colspan="4">MAX. HOP COUNT</td><td colspan="4">SPARE</td></tr>
<tr><td colspan="8">ORIGINATOR ADDRESS</td></tr>
<tr><td colspan="8">DESTINATION/RELAY STATUS BYTE 1</td></tr>
<tr><td colspan="8">DESTINATION/RELAY ADDRESS 1</td></tr>
<tr><td colspan="8">DESTINATION/RELAY STATUS BYTE 2</td></tr>
<tr><td colspan="8">DESTINATION/RELAY ADDRESS 2</td></tr>
<tr><td colspan="8">.<br>.<br>.</td></tr>
<tr><td colspan="8">DESTINATION/RELAY STATUS BYTE N</td></tr>
<tr><td colspan="8">DESTINATION/RELAY ADDRESS N</td></tr>
</table>

FIGURE 26. Intranet header.

5.4.1.1.1. Version. The version number shall indicate which version of the intranet protocol is being used. The current value is 0.

5.4.1.1.2. Message type. The message type is a number 0 to 15 which indicates the type of data in the data field of the intranet layer packet. Table XI lists all the valid message types. Since the message type field in the intranet header is always present in information frames of any link layer type, it is used to determine what type of data is borne by the information frame.

TABLE XI. Intranet message types.

| | |
|---|---|
| 0 | Reserved |
| 1 | Intranet Acknowledgment |
| 2 | Topology Update |
| 3 | Topology Update Request |
| 4 | IP Packets |
| 5 | ARP/RARP |
| 6 | XNP |
| 7 | MIL-STD-2045-47001 Header |
| 8 to 15 | Spare |

5.4.1.1.2.1 ARP/RARP. The Address Resolution Protocol (ARP) is defined in Request For Comment (RFC) 826. The Reverse Address Resolution Protocol (RARP) is defined in RFC 903. For hardware type (ar&hrd) = 22 (CNR), the source hardware address (ar$sha) field shall contain the data link address (range 0-127). The hardware address length (ar$hln) field shall specify the number of octets in the hardware address field.

5.4.1.1.2.2 XNP. XNP messages are used for CNR management. See Appendix E.

5.4.1.1.2.3 MIL-STD-2045-47001 header. When set to 7, the Intranet message type field specifies a direct connection from the Intranet layer to the MIL-STD-2045-47001 Application header.

5.4.1.1.3. Intranet header length. The Header Length shall be the number of octets in the intranet header only. The minimum length is 3 octets.

5.4.1.1.4. Type of service. The Type of Service (TOS) field in the intranet header is modeled exactly upon the IP TOS field, including the Precedence subfield.

5.4.1.1.5. Message identification number. The message identification number shall be a number, 0-255, assigned by the originating hosts. Together with the originator address it uniquely identifies each packet being relayed.

5.4.1.1.6. Maximum hop count. The maximum hop count shall be the maximum number of times this intranet packet can be relayed on the radio net. A hop is defined as a single link between two adjacent nodes. This number is set by the source host and is decremented each time a device receives the intranet header. If the maximum hop count is decremented to 0, the intranet packet shall not be forwarded any further, however it shall be processed locally if applicable.

5.4.1.1.7. Destination/Relay status byte. The Destination/Relay Status Byte (see Figure 27) shall provide intranet routing information for each destination and/or relay address. In addition, this octet also selects end-to-end intranet acknowledgments.

| *LSB* *0* | *1* | *2* | *3* | *4* | *5* | *6* | *MSB* *7* |
|---|---|---|---|---|---|---|---|
| **Distance** | | | **REL** | **Relay Type** | | **DES** | **ACK** |

FIGURE 27. Destination/Relay status byte.

5.4.1.1.7.1. Distance. The distance subfield specifies how many hops a relay address is away from the originator node. For final destination addresses which are not relayers, the distance field gives the number hops from the originator node to the destination node.

5.4.1.1.7.2. REL. The REL bit when set indicates that the given node will participate in relaying.

5.4.1.1.7.3. Relay type. The Relay Type bits indicate the type of relaying to be performed. The relay types are defined in Table XII. The value of 0 indicates source directed relay defined in Appendix I.

TABLE XII. Relay types.

| | |
|---|---|
| 0 | Source Directed Relay |
| 1 | Spare |
| 2 | Spare |
| 3 | Spare |

5.4.1.1.7.4. DES. When the DES bit is set, the following address is at least one of the destinations for the packet. The following address may also be a next hop relay for another destination.

5.4.1.1.7.5. ACK. The ACK bit when set requests end-to-end (ETE) intranet acknowledgments for the associated node only. The procedure for end-to-end intranet acknowledgment follows.

5.4.1.1.7.5.1 Receiving ETE intranet ACK. When a node receives an Intranet Packet with the ACK bit set, it shall return an Intranet Acknowledgment packet at the first possible opportunity. The Intranet Acknowledgment packet shall have the same Message Identification Number as the received Intranet Packet. The path specified in the Intranet Acknowledgment packet shall be the reverse path specified in the received Intranet Packet. The Intranet Acknowledgment packet shall specify exactly one destination, namely the originator of the received Intranet Packet.

5.4.1.1.7.5.2 ETE intranet ACK timeout. When a node sends an intranet packet with the ACK bit set, it shall start its ETE acknowledgment timer. The ETE acknowledgment timer is an intranet parameter that defines the period within which a sending station shall expect an acknowledgment from the destination(s). The value of the ETE acknowledgment timer shall be a fixed factor plus a factor proportional to the number of hops required for all destinations to receive the packet. The default value for the fixed factor shall be 20 seconds. The default value for the proportional factor shall be twice the value of the data link layer acknowledgment timer, multiplied by the number of hops to the furthest destination. The maximum value for the ETE Intranet Acknowledgment Timer shall be 10 minutes (600 seconds).

5.4.1.1.7.5.3 Receiving an intranet acknowledgment packet. When an Intranet Acknowledgment Packet is received, that destination shall be removed from the list of destinations from which an acknowledgment is required. When all destinations have acknowledged, no further action is taken at the Intranet Layer.

5.4.1.1.7.5.4 Expiration of the ETE intranet ACK timer. When the ETE acknowledgment timer expires, the sending station shall retry the transmission of the Intranet packet. The number of retries shall be a value between 1 and 4, with a default of 2. Each retransmission may use a new path to each unacknowledging destination. If only one path exists to a destination, that path shall be used until either the acknowledgment is received or the maximum number of Intranet retransmissions is exhausted. If no acknowledgment is received after the maximum number of Intranet retransmissions, an IL-Status-Indication would be sent to the upper layer indicating acknowledgment failure.

The retransmitted packet shall have a recreated Intranet Header with the same Type of Service field and Message Identification Number. The Intranet Header shall be recreated to specify the new path to the destination. This recreated Intranet Header shall not specify paths to nodes that have already acknowledged the message. This recreated Intranet Header shall not specify paths to nodes from which an acknowledgment is not required. This recreated Intranet Header shall include paths to all nodes from which an acknowledgment is required, but from which an acknowledgment has not yet been received.

5.4.1.1.8. Originator address. The originator address shall be the link layer address of the originating node.

5.4.1.1.9. Destination/Relay address. The intranet destination/relay address shall be the 7-bit link layer address. It is either the destination address for an intranet packet or the relay address. The extension bit (LSB) is available for use by relaying procedures.

5.4.1.2 Topology update. Connectivity and topology information of the intranet is essential for a node to initiate and/or perform intranet relay. Each node on the radio network needs to determine what nodes are on the network and whether they are 1 or more hops away. This information can be partially determined passively by listening to a node's traffic at layers 3a and 2 and/or actively by exchanging topology information. The topology update data structure, defined in Figure 28, has been provided for nodes in the intranetwork to exchange topology and connectivity information. Appendix H specifies the procedure for exchanging topology information between nodes.

| *LSB 0* | *1* | *2* | *3* | *4* | *5* | *6* | *MSB 7* |
|---|---|---|---|---|---|---|---|
| Topology Update Length | | | | | | | |
| Topology Update ID | | | | | | | |
| Node 1 Address | | | | | | | |
| Node 1 Status Byte | | | | | | | |
| Node 1 Predecessor Address | | | | | | | |
| Node 2 Address | | | | | | | |
| Node 2 Status Byte | | | | | | | |
| Node 2 Predecessor Address | | | | | | | |
| ... | | | | | | | |
| Node N Address | | | | | | | |
| Node N Status Byte | | | | | | | |
| Node N Predecessor Address | | | | | | | |

FIGURE 28. Topology update data structure.

5.4.1.2.1. Topology update length. The Topology Update Length field is the length in octets of topology update data. Topology Update Length shall not exceed the MTU minus 8 octets.

5.4.1.2.2. Topology update ID. The Topology Update ID is a number from 0 to 255. Together with the originator's link layer address, the Topology Update ID uniquely identifies each topology update generated by the originating node. This number is incremented by 1 every time a topology update is generated. The Topology Update ID for the first topology update generated shall be 1.

5.4.1.2.3. Node address. The Node Address is the link layer address of node in the intranet.

5.4.1.2.4. Node status byte. The *i*th Node Status Byte characterizes the link between originator host (the host whose address appears in the originator address of the intranet header) and the *i*th node whose address immediately follows the Node Status Byte as defined in Figure 29.

| *LSB 0* | *1* | *2* | *3* | *4* | *5* | *6* | *MSB 7* |
|---|---|---|---|---|---|---|---|
| LINK QUALITY | | | HOP LENGTH | | | NR | QUIET |

FIGURE 29. Node status byte.

5.4.1.2.4.1 Link quality. The Link Quality subfield for the *i*th node provides an assessment of the link quality between the *i*th node predecessor and the *i*th node. The Link Quality is set to 0 if the quality of a link is unknown. Increasing Link Quality value infers a poorer link. Link Quality is set to 7 to indicate that the node is static. Static nodes have pre-assigned data link addresses, and do not affect Intranet Topology as they enter and leave the network. Table XIII lists the Link Quality values.

TABLE XIII. Topology link quality values.

| Link Quality | Description |
|---|---|
| 0 | Unknown |
| 1 | Best Link |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | Worst Link |
| 7 | Static Node |

5.4.1.2.4.2. Hop length. The Hop Length subfield defined in Table XIV indicates the distance in hops from the source to the given node. Hop Length = 1 means the node can be reached directly by the source - no relays are required. A hop length of 0 indicates the source node itself or that the source may know that node should be on the network but does not know where it is.

5.4.1.2.4.3. NR. The NR bit when set to 1 indicates that the node is not participating as a relayer.

5.4.1.2.4.4. Quiet. The Quiet bit, when set, indicates the node is either in quiet mode or going into quiet mode and cannot transmit any traffic.

TABLE XIV. Hop length values.

| Hops | Description |
|---|---|
| 0 | Unknown |
| 1 | 0 Relays required |
| 2 | 1 relays required |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | 6 or more relays required |

5.4.1.2.5. Node predecessor address. Each node maintains intranet topology as routing tree rooted at itself. For the *i*th node in the routing tree, the Node Predecessor Address is the link layer address of the node one branch up from the *i*th node in the routing tree. The predecessor for all nodes within 1 hop of the originator node, which is the root of the routing tree is the originator node. The predecessor for all nodes n hops away is a node which is n-1 hops away from the originator and that can talk directly with the node n hops away. If the *i*th node has not been integrated into the source node's routing tree, the Node Predecessor Address for the *i*th node should be set to 0.

5.4.1.3 Topology update request message. The Topology Update Request message, Intranet Relay Message Type 3, consists of the Intranet Header with one originator and possibly multiple destination addresses. No Information field is permitted. The maximum hop count and distance field shall be set to 1. The Relay, Relay Type, and ACK bit shall be always zero. The DES bit shall be always 1. The destination address in the Intranet Header shall be the link layer address to which this request has been made. The addressing at the link layer may be either the broadcast address or the individual link layer addresses.

5.4.1.4 Intranet layer interactions. The Intranet Layer (Layer 3A) interacts with both the next higher layer and next lower layer to pass or receive information regarding services requested or performed. Three primitives are used to pass information for the sending and receiving of data across the upper layer boundary.

a. Requests for transmission of data are sent by the upper layer, using the Intranet layer (IL) Unitdata Request primitive, with the following parameters:

IL-Unitdata Request
- Destination(s)
- Source
- Quality of Service
- Precedence
- Throughput (Normal/High)
- Delay (Normal/Low)
- Reliability (Normal/High)
- Data/Data Length
- Intranet Message Type
- IL-Unitdata-ID

b. Indications are provided to the upper layer when data is received through the IL-Unitdata Indication primitive, with the following parameters:

IL-Unitdata Indication
- Destination(s)
- Source
- Data/Data Length

IL-Status Indication
    Acknowledgment failure
    Intranet Path Status
    IL-Unitdata-ID

c. Descriptions of the above parameters follow:

1. The destination can be 1 to 16 individual or data link layer multicast (including global) addresses.

2. The source address is the data link layer individual address of the outgoing link.

3. Quality-of-service parameters are used in determining the service provided by the Intranet layer. Quality of service parameters are identical to those at the data link layer, described in 5.3.16c(4).

(a) Precedence shall be mapped from the TOS field (see 5.4.1.1.4) as follows:

| PPP | Precedence |
|---|---|
| 111 | Network Control |
| 110 | Internet Control |
| 101 | CRITIC/ECP |
| 100 | Flash Override |
| 011 | Flash |
| 010 | Immediate |
| 001 | Priority |
| 000 | Routine |

where the least significant bit is shown to the right under PPP.

(b) The other Quality of Service parameters shall be mapped from the TOS field (see 5.4.1.1.4) as follows:

| | |
|---|---|
| T=0 | Normal Throughput |
| T=1 | High Throughput |
| D=0 | Normal Delay |
| D=1 | Low Delay |
| R=0 | Normal Reliability |
| R=1 | High Reliability |

(c) The end-to-end intranet acknowledgment procedures described in 5.4.1.1.7.5 shall be used when R=1, and relaying is used to deliver the message to any destination of the packet.

4. Data/Data Length is the block of data exchanged between the Intranet layer and its upper layer (i.e. IP) user, and an indication of the data's length.

5. Acknowledgment Failure is an indicator to inform the upper layer if an Intranet acknowledgment was not received from the remote station when high reliability was requested in an IL-Unitdata Request.

6. Whenever a node becomes reachable or unreachable, an Intranet Path Status indication is sent to the upper layer identifying the destination link address.

7. Intranet Message Type is defined in 5.4.1.1.2.

8. IL-Unitdata-ID is an indicator established by the upper layer in the IL-Unitdata Request and used to associate a subsequent IL-Status Indication acknowledgment status with that request.

5.4.2. Subnetwork Dependent Convergence Function (SNDCF). The International Organization for Standardization description of the network layer defines a subnetwork dependent convergence layer, between the intranet and internet layers. The layer performs the necessary functions to assure that IP expected services are provided within a particular subnetwork type. The functions required to converge IP services within a MIL-STD-188-220 subnetwork (layers 3a and below) services are: (1) determine the complete list of IP final destinations within the subnetwork; (2) determine the associated subnetwork address(es) for each IP address; and (3) determine the subnetwork type of service requirements (reliability, throughput, delay, immediate retransmission and precedence). The preceding information is contained in the IP header. If the IP protocol implementation does not provide the required information through an inter-layer interaction, the SNDCF must examine the IP header fields to "learn" the destinations and type of service. The SNDCF is only active for an IL-Unitdata request from the IP. The convergence functions for a MIL-STD-188-220 subnetwork using the Selective Directive Broadcast protocol described in RFC 1770 are described below.

5.4.2.1 Determine destination function. The Determine Destination function obtains final destination information from the IP header. The IP destination address field of the IP header is examined first. If the address in that field is an individual address, broadcast address (all 1's), or multicast address (Class D IP address), the Determine Destination function is complete and it passes the single IP address to the Address Mapping Function. If the IP destination address is a directed broadcast address, (all ones in the host portion of the IP address only) the network portion of the IP address (NET ID) is compared to the local NET ID. If the NET ID portion of the directed broadcast address is not the same as the local NET ID, the single IP directed broadcast address is passed to the Address Mapping function. If the NET ID portion of the directed broadcast IP address is the same as the local NET ID, the Determine Destination function examines the IP option field for the presence of the multi-address IP option (selective directed broadcast). If the option is present, the list of individual IP addresses contained in the option is passed to the Address

Mapping function.  If the option is not present, the single IP directed broadcast address is passed to the Address Mapping function

5.4.2.2.  Address mapping function.  The SNDCF Address Mapping function is provided one or more addresses from the Determine Destinations function.  The Address Mapping function determines the data link address(es) associated with an IP address.  The Address Mapping function accesses an information base to determine the data link layer address associated with an IP address.  IP broadcast (all 1's) addresses and directed broadcast addresses for the local subnetwork are mapped to the data link global address.

5.4.2.3  Type of service function.  The SNDCF Type of Service function obtains the IP service requirements from the IP Type of Service header field.  The values in the field are provided to the Intranet Layer protocol.

5.4.2.4  Intranet send request.  After the SNDCF layer performs all of its functions, it issues an IL-Unitdata Request that includes the list of data link addresses and the Type of Service data.

# 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Subject term (key word) listing. The follow key words and phrases apply to this document.

- Data Communications Protocol
- Digital Message Transfer Device
- Error Detection and Correction
- Interoperability
- Open Systems Interconnection
- Packets
- Radio
- Relay
- Segmentation

6.2 Issue of the DoD index of specifications and standards. When this document is used in procurement, the applicable issue of the DoDISS must be cited in the solicitation.

6.3 Interoperability considerations. This section addresses some of the aspects that terminal designers and systems engineers should consider when applying MIL-STD-188-220 in their communications system designs. The proper integration of MIL-STD-188-220 into the total system design will ensure the interoperability of stations that exchange information over a data communications link consisting of a DMTD, a transmission channel, and a DMTD or C4I system.

6.3.1 Transmission channel. For the purpose of this document, the transmission channel (from the transmitter to the receiver) is considered transparent to the DMTD subsystem. However, the transmission channel must be interoperable within itself. The transmission channel may be secured or non-secured, using such media as line-of-sight (LOS) radio, high frequency (HF) radio, wireline, and SATCOM.

6.3.2 Physical interface. The specific details of the physical interface for connecting DMTDs to the equipment that implements the transmission channel are beyond the scope of this document. The actual physical connections will depend on the interface characteristics required by the particular transmission equipment. These unique physical interface characteristics may be defined in the equipment specifications or in technical interface specifications. Therefore, the requirements for the electrical features (such as data, clock, and control) and mechanical features (such as connectors, pin assignments, and cable) of the connection between the DMTD and the associated transmission channel equipment are left to the equipment designer. The data signaling format (that is, NRZ, FSK, CDP) is specified in this document at the standard interface, because it is an interoperability parameter. The design philosophy is that what appears at the input end of the transmission channel should be the same at the output end. Requirements for effecting a working interface to specific radios are provided in the following subparagraphs.

6.3.2.1 SINCGARS system improvement program (SIP) receiver/transmitter (R/T) interface. The DTE (DMTD or C4I system) interacts with the DCE via an X.21 data interface and an External Control Interface. When the precedence level of the transmission changes, the DTE will set the precedence level for the new transmission via the External Control interface. This precedence level will correspond to the frame with the highest precedence value within the series of concatenated frames.

6.3.2.1.1 Carrier sense multiple access (CSMA) network access. Although all SINCGARS SIP R/Ts in a given network are not required to use the same CSMA slot offsets and limits for voice and/or precedence levels, it is highly recommended that the same slot settings be used within a network. All SINCGARS SIP R/Ts in a network must be using the same slot width (18ms - FH; 54ms - SC) and the same mode of operation (plain text or cypher text).

6.3.2.1.2 Network busy sensing and receive status. The presence of multiple stations on a single random access communications network requires voice/data Network Busy Sensing and the use of network access control to reduce the possibility of data collisions on the net. The combined Data and Voice Networks require cooperation between the DTE (DMTD or C4I system) and the DCE.

The DCE indicates the presence of receive data and voice via the X.21 Indication line "I" signal. A precise determination of the network status is obtained via the X.21 DTE Receive line "R" signal in combination with the "I" signal:

| | |
|---|---|
| I = OFF and R = 1's -> | Idle/Transmission Completed |
| I = OFF and R = Flags -> | Data being transmitted |
| I = ON and R = Flags -> | Data being received |
| I = ON and R = 1's -> | Voice operation if this condition persists for more than 250 mSec. From 0 to 250 milliseconds the radio is busy, but voice or data reception can't be determined until either the presence of flags on the R-line for data or the expiration of 250 milliseconds when voice reception is assumed. |

The transmission of data takes effect by driving the X.21 Control line "C" (push-to-talk) and DTE Transmit line "T", as follows:

Verify I = OFF and R = 1's, then assert C = ON and send flags T = Flags

Verify I = OFF and R = Flags, then transmit data T = Data

Upon transmit completion, assert C = OFF and send T = 1’s

The time between the SINCGARS SIP R/T detection of network busy and the determination of network busy with voice is added to any suspended timers. The timers are suspended in the INC only after network busy with voice is indicated. Therefore, adding the time period in which the radio detects network busy with "something" until network busy with voice is determined accounts for the period of time voice was actually present.

6.3.2.1.3 Network timing model parameters. The Network Timing Model is described in Appendix C. Parameter values specific to the SINCGARS SIP radio are provided in Table XV.

TABLE XV. SINCGARS SIP - Packet Mode: 16 kbps digital (milliseconds).

| | EPRE* | PHASING | ELAG* | TURN |
|---|---|---|---|---|
| Frequency Hopping Cipher Text | 21 | 0 | 600 | 30 |
| Frequency Hopping Plain Text | 21 | 0 | 600 | 30 |
| Single Channel Cipher Text | 57 | 0 | 143 | 30 |
| Single Channel Plain Text | 57 | 0 | 143 | 30 |

* **Note:** EPRE & ELAG assume RENAD & Coupled Acknowledgment (offset=0, Limit=0)

6.3.2.1.4 Other SINCGARS SIP implementation details.

a. The RE-NAD slot assignment for Type 3 PDUs is offset=0, limit=0. The "offset" is the number of the first slot while the "limit" is the number of slots associated with the particular parameter (e.g., a precedence level). Offset=0, limit=0 means there is no randomized delay associated with the Type 3 PDUs or the returned Type 3 acknowledgments in the SIP R/T due to the RE-NAD process. The 0-second Immediate Mode scheduler is used with these PDUs and returned acknowledgments so that no additional randomized delay is incurred from the INC (where the scheduler is implemented).

b. The SINCGARS SIP R/T does not manipulate any trailing flags included in the data stream presented to it. These flags are transmitted over the air.

c. From the SINCGARS SIP R/T perspective, any trailing flags are part of the data stream and should be calculated into DATA.

d. The DTE (e.g. INC) must achieve synchronization with the SINCGARS SIP R/T within four flag sequences. Data may be sent upon detection of a valid flag sequence.

6.3.2.2 SINCGARS ICOM R/T interface.

6.3.2.2.1. NRZ physical interface between DTE and R/T. The SINCGARS ICOM digital data interface to a DTE is a synchronous, unbalanced, half-duplex serial interface.

a. The signaling format is non-return-to-zero (NRZ), at voltage levels compatible with those specified in MIL-STD-188-114A for a single receiver load termination.

b. Digital data rates of 600, 1200, 2400, 4800 and 16000 bps are supported by the ICOM R/T. When a data rate below 16000 bps is selected at a transmitter, a Data Rate Adapter (DRA) internal to the ICOM upconverts the data to 16000 bps, using majority logic forward error correction techniques.

c. The ICOM R/T also provides a receive squelch indication to the DTE when channel activity is sensed.

6.3.2.2.2. Network busy sensing and receive status. Network Busy Sensing provides a mechanism to manage channel access among members of a common network. Without managed channel access, multiple stations attempting simultaneous transmissions will collide, degrading network performance. Managing channel access also minimizes the network performance loss due to mixing both voice and data in a common net.

a. For both voice and digital data receptions, the DCE provides a receive squelch indication via the Analog Data Mode Control_Not (ADMC_N) line. This ADMC_N squelch indication is a composite signal from several internal sources. Using this signal, the worst case network busy detect times are 350 milliseconds for frequency hopping and 100 milliseconds for single channel.

b. For digital data receptions, the DCE presents a synchronous clock on the Digital Data Clock Out (DDCO) line. ADMC_N will typically precede DDCO for all digital data receptions. The exception is for PT 16000 bps data, when both ADMC_N and DDCO will be coincident.

c. For voice receptions, the DCE will provide a receive squelch indication via ADMC_N, but will not present DDCO.

d. If both ADMC_N and DDCO are considered as binary signals, there are four possible indications which a DTE can use to infer network status. Table XVI summarizes the four possible receive states and their interpretation.

TABLE XVI. SINCGARS ICOM receive states.

| | ADMC_N Active | ADMC_N Inactive |
|---|---|---|
| DDCO Active | Digital data reception | Not Applicable |
| DDCO Inactive | Voice reception | R/T idle |

6.3.2.2.3 Network timing model parameters. The Network Timing Model is described in Appendix C. Parameter values specific to the SINCGARS ICOM radio are provided in Tables XVII through XX.

TABLE XVII. SINCGARS ICOM: 16 kbps digital (milliseconds).

| | EPRE | PHASING | ELAG | TURN |
|---|---|---|---|---|
| Frequency Hopping Secure | 340 | 0 | 154.42 | 90.58 |
| Frequency Hopping Unsecure | 200 | 0 | 153.42 | 36.58 |
| Single Channel Secure | 370 | 0 | 1.338 | 14.102 |
| Single Channel Unsecure | 300 | 0 | 0.42 | 155.958 |

TABLE XVIII. SINCGARS ICOM: 4800 bps digital (milliseconds).

| | EPRE | PHASING | ELAG | TURN |
|---|---|---|---|---|
| Frequency Hopping Secure | 370 | 0 | 156.96 | 88.04 |
| Frequency Hopping Unsecure | 230 | 0 | 155.986 | 34.014 |
| Single Channel Secure | 400 | 0 | 3.88 | 221.52 |
| Single Channel Unsecure | 329 | 0 | 2.96 | 160.84 |

TABLE XIX. SINCGARS ICOM: 2400 bps digital (milliseconds).

| | EPRE | PHASING | ELAG | TURN |
|---|---|---|---|---|
| Frequency Hopping Secure | 370 | 0 | 157.52 | 87.48 |
| Frequency Hopping Unsecure | 230 | 0 | 156.58 | 33.42 |
| Single Channel Secure | 400 | 0 | 4.44 | 200.96 |
| Single Channel Unsecure | 329 | 0 | 3.51 | 161.49 |

TABLE XX. SINCGARS ICOM: 1200 bps digital (milliseconds).

| | EPRE | PHASING | ELAG | TURN |
|---|---|---|---|---|
| Frequency Hopping Secure | 370 | 0 | 158.8 | 86.2 |
| Frequency Hopping Unsecure | 230 | 0 | 157.8 | 32.2 |
| Single Channel Secure | 400 | 0 | 5.69 | 207.51 |
| Single Channel Unsecure | 329 | 0 | 4.75 | 171.85 |

6.3.2.3 HAVEQUICK II R/T interface.

6.3.2.3.1 Network timing model parameters. The Network Timing Model is described in Appendix C. Parameter values specific to the HAVEQUICK II radio are provided in Tables XXI and XXII.

6.3.2.4 COMSEC interoperability. The COMSEC function provides a link encryption capability. In the traditional COMSEC mode of operation, the COMSEC function (normally implemented in ancillary equipment) is considered part of the transmission channel. In the embedded COMSEC mode, the COMSEC function is an integral part of the DMTD subsystem.

TABLE XXI. HAVEQUICK II: 16 kbps digital (milliseconds).

| | EPRE | PHASING | ELAG | TURN |
|---|---|---|---|---|
| Frequency Hopping<br>Convolutional (1/3)<br>Secure | 851<br>plus COMSEC | 10 + 7.2/hr | 0 | 930 |
| Frequency Hopping<br>No Convolutional<br>Secure | 851<br>plus COMSEC | 10 + 7.2/hr | 0 | 930 + 7.2/hr |
| Frequency Hopping<br>No Convolutional<br>Unsecure | 851 | 105 | 0 | 930 + 7.2/hr |
| Single Channel<br>Secure | 174<br>plus COMSEC | 0 | 0 | 176 |
| Single Channel<br>Unsecure | 174 | 105 | 0 | 176 |

TABLE XXII. HAVEQUICK II: analog (milliseconds).

| | EPRE | PHASING | ELAG | TURN |
|---|---|---|---|---|
| Frequency Hopping<br>Secure | 851<br>plus COMSEC | 0 | 0 | 930 |
| Frequency Hopping<br>Unsecure | 150 | 105 | 0 | 97 |
| Single Channel<br>Secure | 174<br>plus COMSEC | 0 | 0 | 176 |
| Single Channel<br>Unsecure | 150 | 105 | 0 | 97 |

6.3.3 Data link layer. The following implementation details should be considered when implementing the data link layer of MIL-STD-188-220:

a. Figure 9 (5.3.1, Transmission Header) should be interpreted with the LSB on the left as in Figure 14. Therefore, the first bit of the Transmission Header that is transmitted (after the flag) will be the FEC selection bit and the last bit transmitted will be bit 9 of Figure 10.

b. The last 2 sentences of 5.3.1 says that the TDC block for the 12-bit TWC and 64-bit TH contains seven 24-bit codewords, encoded as a 168-bit TDC block. 5.3.14.2 says that if the (12+64=76, plus a few inserted zeros) data bits do not divide into an integral number of 12-bit segments, fill bits of zeros are added to the end. Note that this does NOT require the physical layer to parse the TH, since the length of the TH is fixed at 64 bits (see Figure 9).

c. Reliable broadcast involves the need for stations to return an acknowledgment to the originator of messages that are received with only the global data link address (see 5.3.4.2.2.2.6) -- the broadcast address is used at higher protocol layers) -- and the receiving station is not individually addressed in the message. There is no requirement for reliable broadcast at the Intranet or Data Link layer.

d. Type 4 acknowledgments (DRR and DRNR are discussed in 5.3.7.3.5.3.1.2 and 5.3.7.3.5.2.3, respectively) may be transmitted twice. The second transmission of the DRR/DRNR should be concatenated with other data link frame transmissions. The DTE should not access the network merely to transmit the second DRR/DRNR.

e. When a station receives an out-of-sequence I frame (see 5.3.7.2.5.4) it may send either an REJ or SREJ, depending upon whether the station can perform resequencing. A station should send SREJ when it can resequence received I frames and should send REJ otherwise.

f. N2 (see 5.3.8.1.1d) is the number of permitted re-transmissions. The number of times that a message may be transmitted is N2+1.

g. The following definition of Quiet Mode (see 5.3.11.2) will be used: When a station can not determine whether another station is in Quiet Mode, it should assume that the station is not in Quiet Mode. The fact that a station has entered Quiet Mode will be known globally over the internet. While there is a possibility that some stations will not get the information, or will ignore the information; the protocol will not try to fix the problem. Specifically, there is no requirement for the last relayer to issue a proxy acknowledgment for stations that are operating in Quiet Mode.

6.3.4 Intranet layer. The following implementation details should be considered when implementing the data link layer of MIL-STD-188-220:

a. Relayers optionally may collapse the Intranet Header to remove addresses that are not on the path to or from the relaying node (see 5.4.1.1.7.5.1). The destination node would still have sufficient information to return an acknowledgment. Interoperability is not affected because the complete path between originator and destination is not corrupted. Collapsing the Intranet Header would minimize bandwidth utilization but would probably increase processing time at each relayer and could destroy information that might be useful to network management functions.

b. The source node will be included as the first entry in every Topology Update (see 5.4.1.2) sent by the INC. The Node Address and Node Predecessor will be set to the station ID (link address) of the source node. The Quiet and Non-relay Status bits will be set to that station's current status. The hop length field will be set to 0. The remaining entries in the Topology Update have no implied ordering. A node aware only of itself will generate an initial update containing just its own entry.

c. Topology Update messages (see 5.4.1.2) are broadcast unreliably.

d. In the Topology Update Data Structure (Figure 28), the "node address" and "node predecessor address" (see 5.4.1.2.3 and 5.4.1.2.5, respectively) have been implemented in the INC and the IDM in the following manner:

> *Both of these addresses are "the link address of the node in the Intranet". The link address is seven bits long (see 5.3.4.2.2.1). The C/R bit associated with this link address is not required by the Intranet Layer. As such, bits 0 through 6 contain the "link address" used in the node address and node predecessor address. Bit 7 must be zero.*

e. Topology Update (see 5.4.1.2) and Topology Update Request messages (see 5.4.1.3) use Data Link Type 1, unacknowledged, procedures.

f. The precedence of Topology Update (see 5.4.1.2) and Topology Update Request messages (see 5.4.1.3) is user defined.

g. Receiving a Topology Update Request (see 5.4.1.3) indicates an operational two-way (bi-directional) link.

h. It is possible for the Min_Update_Per parameter (see H4.4.3) to take different values on a node-by-node basis within a net. There is essentially no problem unless one of the nodes takes the value 0. Assume node A has this value set to 0. Node A is not permitted to respond to topology requests. Nodes without traffic for this node issue topology update requests to try to set up links. Node A does not respond. Once a node (e.g. B) sets up a valid link with a link layer acknowledgment, a topology update listing this connection is advertised. All other nodes without a link will switch to a 2-hop path using node B as a relayer to node A. Therefore, it is logical that the Min_Update_Per value should be set on a network-wide basis. An alternative solution is available: The non-participant can announce this fact in a Topology Update message that identifies itself in the Node 1 Address field and the Node 1 Predecessor Address field and by setting the NR bit in the Node 1 Destination/Status Byte.

i. I5.3 presents the solution to Source Directed Relay Example 3 as C-E-F-G-H-D. An equally valid solution is D-C-E-F-G-H.

6.3.5 CNR management process.

a. The CNR Management process is recommended to reduce operator burden by providing automated support for the management function.

b. There is no requirement to respond to an XNP Join Request message (see E4.2.1). If operational conditions permit, an interval timer may be used to schedule the retransmission of an XNP Join Request message (see E6.2).

6.3.6 Interoperation with internet protocols.

a. The Technical Architecture requires the IP protocol. Systems implementing Intranet message type 7 (MIL-STD-2045-47001 Header) must also implement Intranet message type 4 (IP Packet).

b. Figure 4 of RFC 791 (Internet Protocol) is interpreted as having the LSB on the RIGHT. This means that the IHL field will be transmitted before the Version Number by the MIL-STD-188-220 lower layers.

c. Message exchanges using MIL-STD-188-220B over CNR should be accomplished using UDP. TCP should be reserved for upper layer services that require Transport Layer reliability.

d. The Internet Address Numbering Authority has assigned OSPF2 if Type Value 85 for CNR.